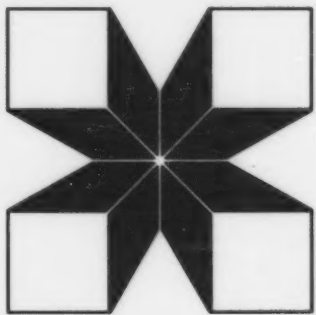


IDRC
CRDI
CIID



C A N A D A

The International Development Research Centre is a public corporation created by the Parliament of Canada in 1970 to support research designed to adapt science and technology to the needs of developing countries. The Centre's activity is concentrated in six sectors: agriculture, food and nutrition sciences; health sciences; information sciences; social sciences; earth and engineering sciences; and communications. IDRC is financed solely by the Parliament of Canada; its policies, however, are set by an international Board of Governors. The Centre's headquarters are in Ottawa, Canada. Regional offices are located in Africa, Asia, Latin America, and the Middle East.

Le Centre de recherches pour le développement international, société publique créée en 1970 par une loi du Parlement canadien, a pour mission d'appuyer des recherches visant à adapter la science et la technologie aux besoins des pays en développement; il concentre son activité dans six secteurs : agriculture, alimentation et nutrition; information; santé; sciences sociales; sciences de la terre et du génie et communications. Le CRDI est financé entièrement par le Parlement canadien, mais c'est un Conseil des gouverneurs international qui en détermine l'orientation et les politiques. Établi à Ottawa (Canada), il a des bureaux régionaux en Afrique, en Asie, en Amérique latine et au Moyen-Orient.

El Centro Internacional de Investigaciones para el Desarrollo es una corporación pública creada en 1970 por el Parlamento de Canadá con el objeto de apoyar la investigación destinada a adaptar la ciencia y la tecnología a las necesidades de los países en desarrollo. Su actividad se concentra en seis sectores: ciencias agrícolas, alimentos y nutrición; ciencias de la salud; ciencias de la información; ciencias sociales; ciencias de la tierra e ingeniería; y comunicaciones. El Centro es financiado exclusivamente por el Parlamento de Canadá; sin embargo, sus políticas son trazadas por un Consejo de Gobernadores de carácter internacional. La sede del Centro está en Ottawa, Canadá, y sus oficinas regionales en América Latina, África, Asia y el Medio Oriente.

This series includes meeting documents, internal reports, and preliminary technical documents that may later form the basis of a formal publication. A Manuscript Report is given a small distribution to a highly specialized audience.

La présente série est réservée aux documents issus de colloques, aux rapports internes et aux documents techniques susceptibles d'être publiés plus tard dans une série de publications plus soignées. D'un tirage restreint, le rapport manuscrit est destiné à un public très spécialisé.

Esta serie incluye ponencias de reuniones, informes internos y documentos técnicos que pueden posteriormente conformar la base de una publicación formal. El informe recibe distribución limitada entre una audiencia altamente especializada.

IDRC-MR302e
October 1991

92-01234/

Value of trees in the small-scale farming sector of Zimbabwe

B.M. Campbell, S.J. Vermeulen, and T. Lynam
University of Zimbabwe, Box MP167, Harare, Zimbabwe

In collaboration with

K.W. Nyamapfene, H.A. Elwell, J. Gambiza, I.M. Grundy, and N. Spicer

Material contained in this report is produced as submitted and has not been subjected to peer review or editing by IDRC Communications Division staff. Unless otherwise stated, copyright for material in this report is held by the author. Mention of a proprietary name does not constitute endorsement of the product and is given only for information.

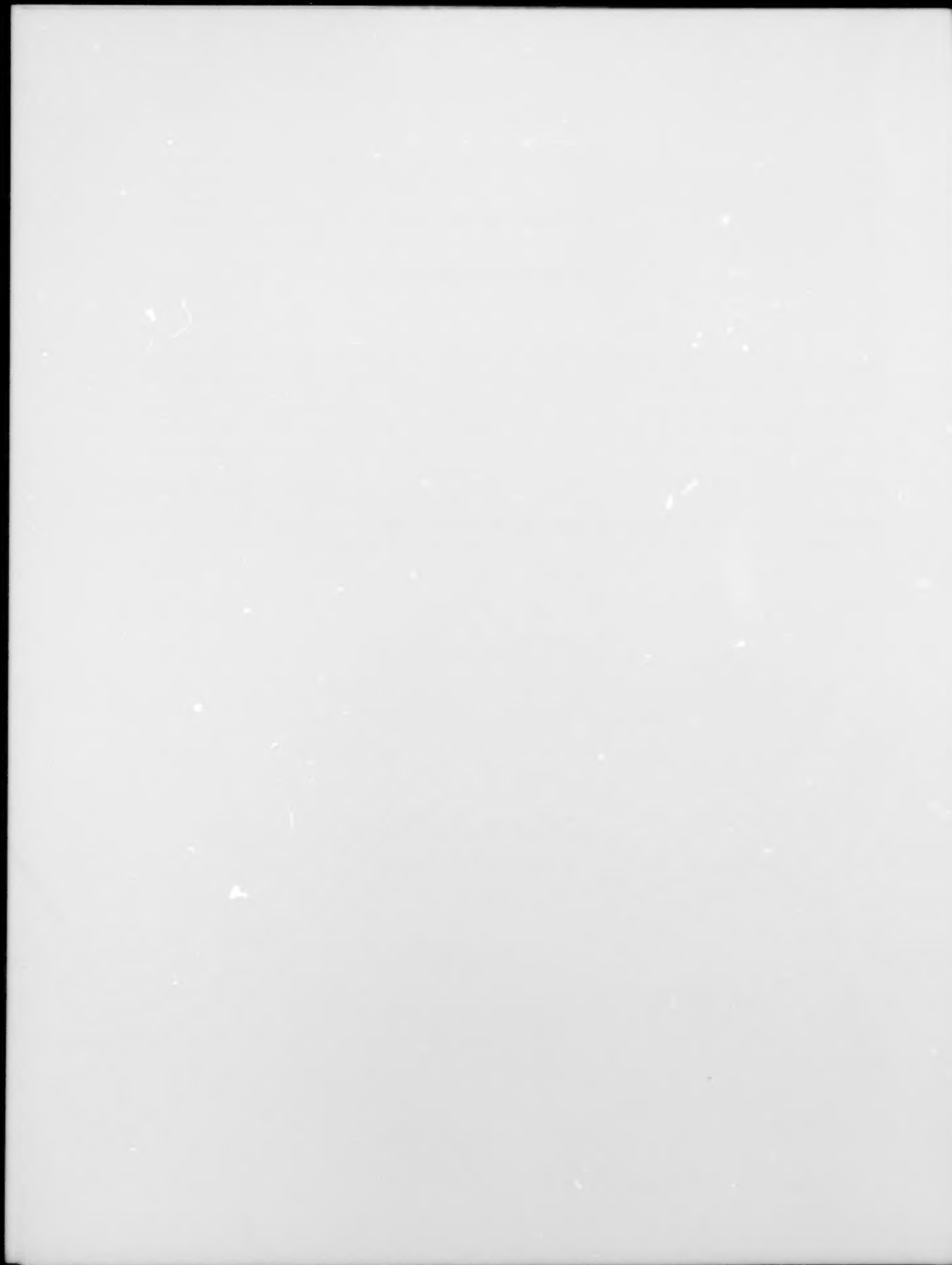
CONTENTS

ACKNOWLEDGEMENTS	iv
EXECUTIVE SUMMARY	1
Objectives	1
Role Trees Play	1
Value of Goods Derived from Trees	1
Contingent Valuation	2
Economics of Interventions	3
Conclusions: Research Priorities and Policy Implications	3
CHAPTER ONE: INTRODUCTION	5
Background	5
Aims	6
Methods	7
CHAPTER TWO: ROLES OF TREES	9
Fruit Production	9
Other Wild Foods from Woodlands	11
Fuelwood	12
Construction Wood	13
Effects on Climate and Soils	16
Crop production	20
Livestock production	22
Trees in Society	24
Shade	25
Medicines	26
Cash Income	26
CHAPTER THREE: VALUATION OF GOODS DERIVED FROM TREES	27
Introduction	27
Fruit	27
Other Wild Foods	29
Fuelwood	29
Construction Wood	29
Crop Production	30
Livestock Production	31
Overall Value of Trees	32
CHAPTER FOUR: CONTINGENT VALUATION	34
Introduction	34
Methods	35
Results	37

CHAPTER FIVE: ECONOMICS OF INTERVENTIONS	44
Woodlots for Poles and Fuel	44
Fodder Banks	45
Tree Nurseries and Subsidised Seedlings	46
Alley Cropping	47
CHAPTER SIX: CONCLUSIONS	49
General	49
Overall Value	50
Fuelwood	51
Fruit Trees	52
Indigenous Woodlands	52
Tree-Planting	52
Stumpage Fees	52
Tenure	53
Integrated Approach	54
REFERENCES	55
APPENDIX 1: VALIDITY CHECKS FOR CONTINGENT ANALYSIS	68
Methods	68
Results	69

ACKNOWLEDGEMENTS

For stimulating and funding this research, we thank the IDRC, and in particular R. Ayling and D. Webb. We are grateful to K. Potter-Witter, R. Bernstein, P. Frost, D. Hancock, P. Mafongoya, F. Matose, L. Mukurumbirwa, A. Mupawaenda, P. Nyathi and M. Rukuni who assisted with questionnaire and methodology finalisation. Valuable comments on earlier drafts were made by P. Bradley, J. Clarke, D. Dore, J. Jackson, P. Frost and G. McGranahan. We thank P. Nyathi for supplying unpublished results on the use of litter. The surveys were conducted under the supervision of E. Mwenje and G. Musona. Photographs were provided by the Ministry of Information, Zimbabwe.



EXECUTIVE SUMMARY

Objectives

1. In this work we examine the value of woodlands and trees to households in the small-scale farming sectors.
2. We approach the question of value from four perspectives:
 - i) Firstly, we examine the roles that trees play.
 - ii) Secondly, we attempt to quantify in monetary terms the value of some of the goods provided by trees.
 - iii) Thirdly, we determine the value of trees using an indirect contingent valuation method.
 - iv) Fourthly, we examine some commonly proposed interventions in terms of their costs and benefits.

Role Trees Play

3. A conceptual model is presented, showing the goods and services provided by trees in small-scale farming systems in Zimbabwe. This illustrates the multi-purpose role that trees play in this sector.
4. The value of trees is undeniable. They provide: almost all of the household energy; many of the timber needs for building, fencing and manufacture of household utensils and agricultural equipment; sources of wild foods, most importantly fruits; inputs to maintain soil fertility in cultivated fields; much of the livestock feed in the late dry season and a host of other more intangible benefits such as spiritual value, medicines and shade.

Value of Goods Derived from Trees

5. The value of trees can be gauged by the practices of farmers: wild fruit trees are conserved in cultivated fields even though government agricultural extension services formerly discouraged this practice; farmers have resisted bush-clearing directives because of the value of browse; and, households spend considerable time collecting woodland litter for application to cultivated fields.

6. The economic valuation of products from trees is crude by necessity: neither the available data nor the situation allow for accurate economic accounting. Because of the use of market prices of goods or their replacements, there tends to be an overestimate of value.

7. Trees in the woodland provide the bulk of goods, as compared to trees scattered in fields or planted around the homestead.

8. Trees provide goods worth about Z\$1000 yr⁻¹ per household. The woodland provides goods to the value of about Z\$200 ha⁻¹ yr⁻¹.

9. Although wood for construction and fuel make up a high percentage of the goods derived from trees, as important, if not more so, are wild fruits from the woodland, browse and litter for cultivated fields. Less important are other foods from woodlands (mushrooms, honey, insects, wild vegetables), materials for utensils, implements and crafts and direct nutrient inputs to the soils of arable fields by scattered trees.

Contingent Valuation

10. Tests of the validity of the results were conducted and indicated that the results produced in the survey were valid reflections of the values of smallholder farmers for tree resources to which they have access.

11. Farmers valued direct inputs to the household (fuel and materials) most, then inputs to other production activities (crop and animal production, ecological services as well as cash income) and lastly shade, health and social services.

12. The value of tree resources could be equivalent to between 3 and 50% of annual household incomes.

13. The values obtained from farmers in the survey reflect the relative scarcity of tree resources with values for total tree resources being higher in low tree cover areas than in high tree cover areas.

14. The added benefits derived from moving from a low tree cover to a high tree cover situation, in terms of improved access to resources appear to be about Z\$228 for materials, Z\$173 for fuel, Z\$122 for crop inputs, Z\$110 for ecological services and Z\$91 for animal feed.

Economics of Interventions

15. The importance of trees in the small-scale sector does not necessarily mean that forestry interventions are economical or acceptable to farmers.

16. Block planting initiatives and seedling provision in the small-scale sector of Zimbabwe have been heavily subsidised by government.

17. Plantations for fodder have been shown to be uneconomical in a number of countries.

18. Unfortunately, there are no economic analyses for agroforestry initiatives such as intercropping or alley-cropping in Zimbabwe.

Conclusions: Research Priorities and Policy Implications

19. The results of the study call for an integrated approach to the development and management of tree resources in the smallholder sector.

20. In the contingent evaluation, the relative values of experts, representing societal values, were notably different from those of smallholder farmers. These differences highlight the need to incorporate farmer values in setting research priorities and policy objectives.

21. The results suggest that greater research effort must be directed towards indigenous woodlands; they need to be managed to ensure high productivity and sustainability.

22. Another research need is to assess the results of a decade of tree-planting initiatives in Zimbabwe. Has there been a tremendous upsurge of interest in tree-planting? Does the level of planting justify the maintenance of the seedling subsidies?

23. In any tree-planting programme, fruit trees should be given highest priority. The previous focus on fuelwood species had little justification.

24. That block planting and seedling provision are uneconomical at present simply means that the "free resources" of the woodland are in relatively large quantities. Only with deforestation will the value of woodland goods rise to a point where tree-planting becomes an attractive option. At this point the cost to society in terms of degradation may be large.

25. The importance of tree resources to the wellbeing of smallholder farmers coupled with the property rights governing access to these resources suggest that tree resources will be undervalued and over-utilised. It is important that research is conducted to identify policies that will lead to a greater awareness of the costs of consuming woodland resources by those benefiting from the consumption. These policies are likely to be concerned with property rights.

26. The prohibitively high costs of tree-planting initiatives are primarily due to labour and exclosures. Detailed labour analyses are required. Because exclosures are needed to protect seedlings from livestock, tree-planting initiatives should be concentrated in the homestead area and in vegetable gardens.

27. Other prohibitive costs for tree-planting come from termiticides and fertilisers, whose use will not be possible by small-scale farmers.

28. Policy options attempting to commercialise trade by the use of "stumpage fees" represent an important way of raising the value of indigenous woodland to cover the replacement cost of wood. The implementation of such fees is, however, problematic.

29. There is an urgent need to develop methodologies to value woodlands and in particular the more intangible benefits of woodlands, such as soil protection, maintenance of soil fertility and maintenance of river flow. This could be approached from at least two perspectives, by quantifying the cost of deforestation and by quantifying the cost of replanting exercises.

CHAPTER ONE: INTRODUCTION

Background

Small-scale, low-input, agro-pastoral systems in Zimbabwe are largely confined to Communal Areas, which occupy just over half of Zimbabwe's land area and accommodate 57% of Zimbabwe's population (Sayce, 1987). Regions designated as Communal Areas are derived from pre-independence Tribal Trust Lands, allocated to subsistence farmers by colonial governments. Since independence in 1980, Resettlement Areas have been created by re-allocation of commercial farming land to small-scale farmers. Farming systems are similar in Communal Areas and Resettlement Areas. Communal Areas tend to be densely populated and relatively deforested (Whitlow, 1980; Whitsun Foundation, 1981; du Toit and Campbell, 1988) and Resettlement Areas are also undergoing rapid deforestation (Grundy et al., in press). In this work we use the term "small-scale farmer" to apply to farmers in Communal Areas and Resettlement Areas.

Small-scale farming systems are found in regions of rainfall between 400 and 800 mm per annum, with the majority at the lower end of this range. Rain falls mainly from November to March. The predominant soils are nutrient-poor sandy soils derived from underlying granite bedrock. They require fertilisation for any significant level of production (Grant, 1981). These factors and others, such as prevalence of crop or livestock diseases, increase the burden of risk on small-scale farmers.

Four agroforestry systems can be identified, centred on main fields, grazing areas, small garden plots and homesteads (Campbell et al., 1991), with transfer of inputs from one system to another attempting to maintain productivity (Swift et al., 1989). The systems tend to remain spatially discrete since shifting cultivation is uncommon (Wilson, 1989a; Campbell et al., 1991).

In 1982, the Forestry Commission implemented the Rural Afforestation Project, a multi-million dollar project initially aimed at halting deforestation and improving the availability of tree resources (Forestry Commission, 1982; World Bank, 1982). The national agricultural extension service also expanded its tree-based activities in the small-scale farming sectors (Agritex, 1982).

Furthermore, there has been an upsurge of research in small-scale farming systems since independence (Clarke, 1983; Balderrama et al, 1988; Scoones, 1990; Wilson, 1990).

Households in Communal Areas have small arable fields, typically about 3 ha in total area (Bratton, 1987; Reh et al., 1988). Maize is the staple crop. Other important crops are finger millet, bullrush millet, groundnuts, sunflowers and cotton.

Croplands are in close proximity to grazing areas, which are used communally. The savanna in most of these grazing areas has been opened by tree cutting for timber and fuelwood or was previously cleared of trees for purposes of cultivation (Campbell et al., 1991). Cattle, goats and chickens are the chief livestock. They are usually kept for home use rather than commercial slaughter (Sayce, 1987). Cattle are used for milk, manure and draught purposes and also have an important exchange value, especially in the payment of lobola (bride price) (Scoones, 1990).

Trees in garden plots and homesteads are the property of the occupier of that land (Wilson, 1989a). In grazing areas trees and their products are used communally and control of their use varies from region to region. The fruits of trees in fields are often regarded as communal property, as long as they are not taken in large numbers to be sold, while other products like timber are the property of the holder of the field (Wilson, 1989a).

The use of trees by small-scale farmers is partly a function of the prevailing vegetation type (Wilson, 1990). On sandy soils, the woodland is composed of miombo species such as *Brachystegia* spp. and *Julbernardia* spp. in higher rainfall regions, while in the drier areas *Terminalia*, *Burkea* and *Combretum* are dominant. Where heavier, more eutrophic soils are found, *Acacia* spp. predominate. One final system of significance is that of *Colophospermum mopane*, which is found under very dry conditions at low altitudes or on sodic soils at higher rainfall.

Aims

In this work, we attempt to answer the following questions. What are the values of the different goods and services that trees provide? Are the forestry-related activities in the small-scale farming sector justified? We approach the question of value from four perspectives:-

1. We look at the many roles trees play in the small-scale farming sector by describing the goods and services that trees provide to households.

2. We attempt to give a monetary value to the goods that trees provide.
3. We value the woodlands by an indirect contingent valuation technique
4. We evaluate the commonly proposed interventions in terms of their economic benefits and costs.

Methods

Most of our material is derived from the literature. In addition, to fill in gaps, we undertook a number of surveys. Questionnaire I was administered in three sites (Table 1) representing high (Mangwende), medium (Shurugwi) and low (Chivi) agro-ecological potential (Vincent and Thomas, 1960). Mangwende Communal area (CA) is in Natural Region IIa (suitable for intensive agriculture), Shurugwi CA in Natural Region III (suitable for semi-intensive farming based on livestock production) and Chivi CA in Natural Region V (which is ideally suitable for extensive livestock and wildlife production). At each site, two areas were selected for survey, one with high and one with low woodland cover. In each of the areas roughly sixty five households were surveyed, giving a total sample of 359 households. This survey mostly covered tree-planting practices, income-generating activities based on woodland products, use of woodland products and questions for the contingent valuation.

Table 1. Characteristics of the three study sites.

	Mangwende	Shurugwi	Chivi
Natural Region	IIa	III	V
Mean annual rainfall (mm)	899	621	572
Population density (1982) (people/km ²)	53.4	50.6	43.2
Average growth rate (%)	2.7	1.4	3.0

Questionnaire II was a small survey of prices in rural markets and business centres in each of the above areas and questionnaire III was administered in Mangwende Communal Area and covered in more detail the meals based on woodland products, cash income from the sale of woodland products, and ownership patterns of woodland-derived implements and utensils.

Unless otherwise stated, all monetary values are reported in Zimbabwe dollars. Where necessary, values are converted to 1991 levels, using the consumer price indices relevant to low-income households. In mid-1991, Z\$1.00 = US\$0.32.

CHAPTER TWO: ROLES OF TREES

A conceptual model showing the main goods and services that trees provide to households is shown in Figure 1.

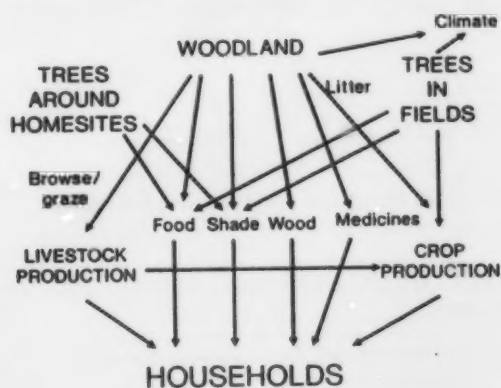


Figure 1. A conceptual model of the flows of goods and services that occur between woodlands/trees and households. For the sake of simplicity, only the main flows are indicated.

Fruit Production

Of respondents in the survey, 98% collect wild fruits (Figure 2). They are collected from grazing areas, from cultivated land where fruit trees have not been cleared or, occasionally, from adjacent commercial farming land. Much of the collection and use of wild fruits is by primary school children (Campbell, 1987). The nutrient composition of wild fruits does not differ from exotic fruits, other than vitamin C contents which are often higher in wild fruits (Wehmeyer, 1966). Wild fruits are particularly important in the late dry season, when food stores are low (Campbell, 1987; Wilson, 1990) and exotic fruits are unavailable (Gumbo et al., 1990). Almost all households use wild fruits to supplement their diets; fewer use wild fruits in main meals. Wilson (1990) found that up to 26% of main meals were fruit meals in the dry season (Table 2) and Clarke (1983) found that wild fruits comprised 25% of the food items in the diet of Tonga people during a drought.

Table 2. Percentage of meals that are fruit meals in a semi-arid region of southern Zimbabwe, by zone, season and household wealth (source: Wilson, 1990).

	% of meals that are fruit meals			
	Boundary		Clayveld	
	Wealthy	Poor	Wealthy	Poor
Dry season	14	26	4	7
Post-harvest	0	12	3	0

n = 263

Clayveld: an area of eutrophic soils with *Acacia/Colophospermum* vegetation

Boundary: an area with both eutrophic and nutrient-poor soils, the latter a miombo system

Fruit trees are highly regarded in Communal Areas. Indigenous fruit trees are selectively retained in fields cleared for cultivation despite attempts by government extension services to promote removal of trees from fields (Campbell, 1987; Wilson, 1989a; Grundy et al., in press). Domestic fruit trees are planted far more commonly than are trees for any other purpose (du Toit et al., 1984; Katerere, 1987; Abel et al., 1989; Gumbo et al., 1990; Grundy et al., in press, Figure 3). Most domestic trees are exotics such as mango or papaw, but indigenous trees are being planted more frequently as seedlings become easier to procure (Gumbo et al., 1990).

Of the vegetation types in Zimbabwe, miombo woodland is richest in fruits. Wilson (1990) found that in an area with both miombo and *Acacia* woodland, fruit for eating comes mainly from the former. Campbell (1987) showed that wild fruit trees are roughly twice as abundant in miombo as in a *Combretum-Acacia* woodland on eutrophic soil and nearly four times as abundant as in mopane woodland.

Other Wild Foods from Woodlands

Wild fruits are not the only food associated with indigenous trees. Also collected from woodlands are wild vegetables, mushrooms, insects and honey (Figure 2). Gathered wild foods are used mainly as relishes, but can also be a basic energy source, especially during times of seasonal hunger or drought (Wilson, 1989b). Ninety-four percent of respondents in the current survey said that their households used gathered wild foods in main meals and 47% said that greater use was made of wild foods during drought years. Table 3 indicates the amount of gathered wild foods used by households in a high rainfall region of Zimbabwe. The use of these foods is highly seasonal, with most foods only available in the wet season (Wilson 1989b).

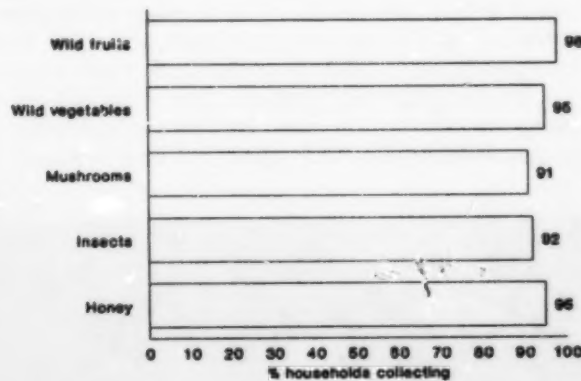


Figure 2. Percentage of small-scale farming households collecting various wild foods from woodlands (n=359).

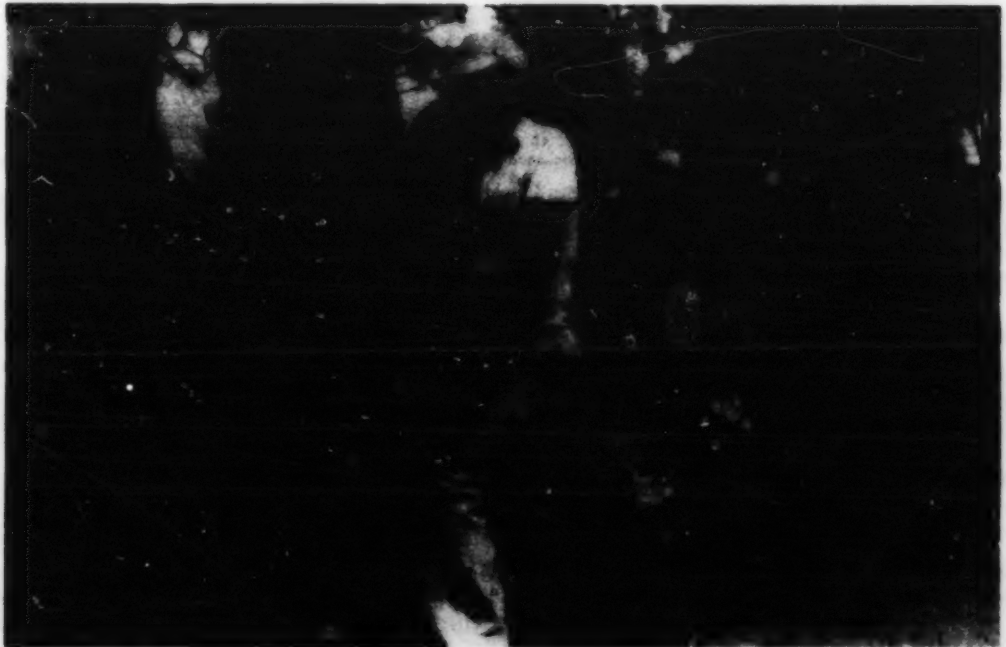
Table 3. Amounts of collected wild foods consumed per household in Mangwende (users only) and the price of the wild foods (Questionnaires II and III).

Amounts of wild foods per year per user-household		Price
Mushrooms	16.2 meals, 1.6 plates/meal (n = 29)	\$1.70/plate
Insects	11.4 meals, 1.2 plates/meal (n = 21)	\$0.40/plate
Wild vegetables	16.8 meals, 2.0 bunches/meal (n = 20)	\$0.40/bunch
Honey	1.8 bottles (n = 12)	\$2.70/bottle

Fuelwood

Fuelwood accounts for 53% of Zimbabwe's total energy consumption and 91% of all fuelwood is used by rural households (Hosier, 1986). Ninety-nine percent of rural households use wood rather than any other fuel source for cooking and heating (du Toit et al., 1984). Each household uses approximately 5.5 tonnes yr^{-1} for these purposes (Grundy et al., in press). Brewing and special occasions add 1 tonne yr^{-1} , bringing the total use for a rural household to about 6.5 tonnes yr^{-1} (Grundy et al., in press).

There is little selection for species in the collection of fuelwood (Campbell and du Toit, 1988; Grundy et al., in press). Most fuelwood is collected locally, little being bought or sold. Du Toit et al. (1984) found that only 0.7% of respondents had purchased fuelwood in the past year, although in a deforested Communal Area near Harare, 48% of respondents had purchased fuelwood in the past year (Burford, 1989). Planting of trees for fuelwood is uncommon. Thirteen percent of respondents in the current survey said that they had planted trees for fuelwood in the past five years (Figure 3).



One of the few people involved in the movement of fuelwood from small-scale farming areas to urban areas.

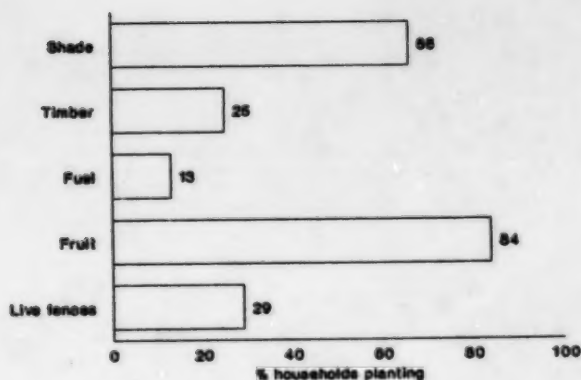


Figure 3. Percentage of small-scale farming households planting trees for different purposes over the last five years (n=359).

Construction Wood

Materials derived from trees are used in the construction of houses, granaries, fences, ox-carts and livestock pens and in the manufacture of agricultural implements, household utensils, furniture, crafts and rope (Figure 4 and Figure 5). Table 4 shows the numbers of wooden products (implements and utensils) owned by individual households that were made from local wood. Most households have a number of cooking sticks and a mortar. They also own many implement handles and a yoke.

The choice of species for different purposes is more selective than for fuelwood (Campbell and du Toit, 1988; Grundy et al., in press). For building purposes, the most highly valued characteristics are length and straightness of poles, durability, and resistance to termites and borers (du Toit et al., 1984; Grundy, 1990). Similar properties are required for pole fencing (Burford, 1989). Alternatives to pole fencing are brush fencing, used by 77% of respondents in this survey, or live fencing, used by 29% of respondents. Fences are especially important around vegetable gardens, where there is a constant threat from livestock (Burford, 1989; Campbell et al., 1991).



Much building wood is used in the making of livestock pens, where on average over 150 poles are used. *Burkea africana* is one of the favoured species for pens.

Table 4. Numbers of implements and utensils (standard deviations in brackets) made of local wood owned per household, their durability and price in Mangwende (Questionnaire III).

	Average number owned per household	Average durability (yrs)	Price (\$)
Cooking sticks	4.7 (2.4)	3.4	2.10
Mortar	1.4 (1.0)	30.1	19.60
Plates	2.0 (2.1)	19.3	6.70
Implement handles	5.6 (2.7)	3.1	4.40
Yokes	1.6 (1.1)	5.2	10.50
n	31	17 to 26	17 to 31

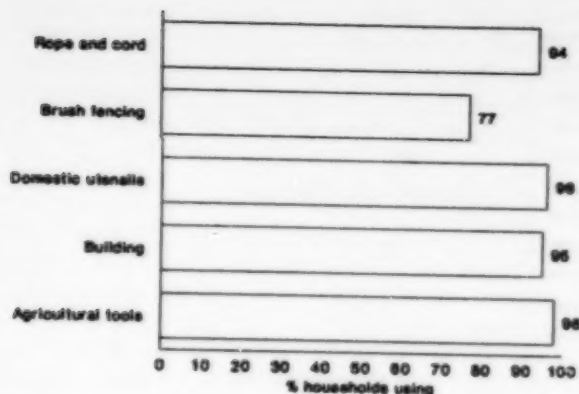


Figure 4. Percentage of small-scale farming households using materials from trees for various construction and manufacturing purposes (n=359).

Construction wood is not commonly bought or sold. Du Toit et al. (1984) found that only 6% of respondents had purchased wood for purposes of construction. In the current survey only 4% of respondents had sold construction wood (Figure 6). In general, small-scale farmers are more interested in planting trees for timber than for fuelwood. Twenty-five percent of respondents in the current survey had planted trees for timber supplies in the past five years (Figure 3).

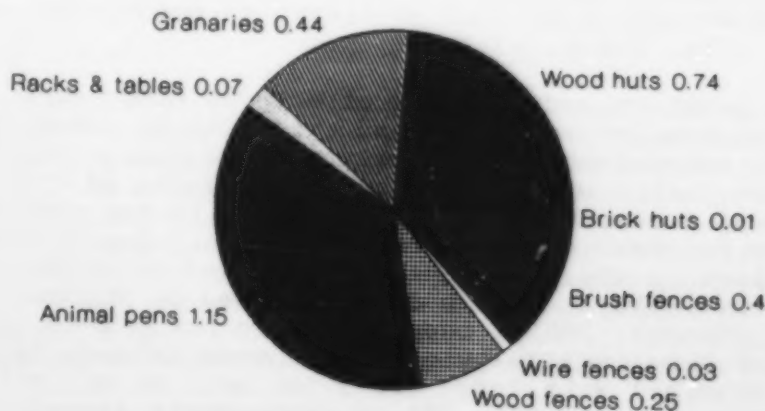


Figure 5. Volumes of wood ($\text{m}^3 \text{hh}^{-1} \text{yr}^{-1}$) used for construction purposes by households in Mutanda Resettlement Area (source: Grundy et al., in press).

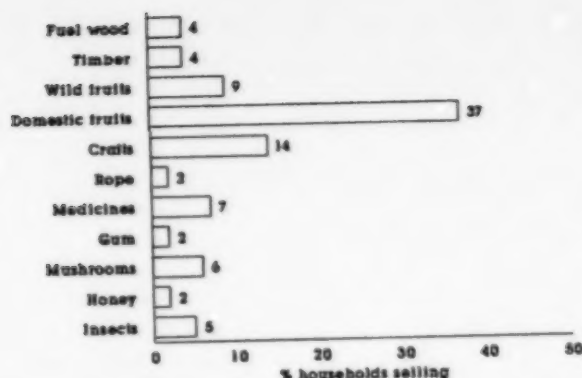


Figure 6. Percentage of small-scale farming households selling various tree products (n=359).

Effects on Climate and Soils

The benefits of incorporating trees into farming systems have long been recognised in Africa (Spears, 1986). However, the role of trees in ameliorating edaphic and climatic conditions for crops and grazing land is often perceived as being incidental to other roles of trees, such as fruit production (Ingram, 1989; Grundy et al., in press). Furthermore, the presence of trees may be detrimental rather than advantageous to crop or livestock production (Barnes, 1979; Spears, 1986; Young, 1987).

Possible positive and negative effects of trees on climate and soils are often species-specific, and this must be taken into account in the assessment of seemingly contradictory results. Trees alter the carbon dioxide and oxygen balances of the atmosphere and, on a global scale, they may be important in the removal of carbon dioxide released by the burning of fossil fuels (Houghton, 1990). On a local scale, trees may affect wind or rain. The benefits of windbreaks have been substantiated by studies in Africa and elsewhere (Spears, 1986), though wind is not viewed as a major problem in Zimbabwean agriculture. Zimbabwean farmers link the provision of rainfall with large trees (as well as hills) (Scoones, 1990). In the current survey, 75% of respondents agreed that having more trees in their district would increase the rainfall. Scoones (1990) quotes an individual farmer as saying, "If you maintain the forests, the rain will continue to come."

Positive impacts of trees on soil fertility are important for both cultivated and grazing land. Soil fertility can be defined as

the capacity of a soil to support growth of plants and is determined by that soil's physical, chemical and biological properties (Ingram, 1990). The effects of improved soil fertility on crops and grazing land will be discussed in the sections on crop production and livestock production respectively; this section will deal with the direct effects of trees on soil fertility.

Organic matter

Practically all studies, whether they involve single trees or closed woodlands, report higher soil organic matter (SOM) under canopies than between canopies (Kellman, 1979; du Preez et al., 1983; Campbell et al., 1988). This phenomenon is attributed to the accumulation of leaf and root litter (Ingram, 1990). Root residues may be especially important since they are not removed from the system and remain when above ground material is burnt or removed (Ingram, 1990). In semi-arid systems, trees tend to contribute a greater amount of above-ground litter than do grasses (Kelly, 1973; Frost, 1985; Gambiza, 1987).

The maintenance of, or increase in, SOM contents of soils result in such benefits as improved soil physical properties, higher cation exchange capacity, which usually reduces leaching (King and Campbell, in preparation), and improved supply of nutrients (Young, 1987). SOM is a good nutrient source because the nutrients are in the form of organic molecules which are protected from leaching and are mineralised slowly to provide a steady release of nutrients in an available form, with a balanced range of primary, secondary and micronutrients (Young, 1987).

Soil structure

The higher level of SOM under tree canopies is usually associated with an increase in the stability, size and grade of crumbs in the topsoil (Spears, 1986; King and Campbell, in preparation). This structural improvement results in a lower bulk density, better aeration and better water holding capacity (Spears, 1986). Dye and Walker (1980) recorded higher infiltration rates on soils carrying *Colophospermum mopane* and *Acacia gerrardii* than on intervening grassy patches in a low rainfall region of Zimbabwe. In a high rainfall region, Campbell et al. (1988) found higher infiltration rates under closed miombo woodland than under open woodland.

Erosion

Tree canopies, roots and litter are all important in the reduction of erosion. The canopy reduces the energy of heavy rainfall, absorbs short light falls and increases the energy of prolonged light rain (Glover et al., 1962; Belsky et al., 1989;

Young, 1989). Whether the net effect is to increase or decrease rain energy is likely to be site and species specific. Litter is considered most important in reducing erosion in semi-arid regions (Kelly, 1973; Stocking et al., 1989) and this importance is reflected in the Zimbabwean soil loss model SLEMSA (Elwell, 1981).

Tree litter is commonly found in greater quantities than grass litter in semi-arid regions (Kelly, 1973; Frost, 1985; Gambiza, 1987). Elwell (1986) found that loss of soil and runoff decreased with increased soil organic carbon content, though some soil samples with high organic carbon content collected from under trees showed hydrophobic tendencies and hence higher runoff and loss of soil. Litter amounts, however, can be highly variable depending on intensity of browse, understorey grazing, leaf disintegration under hoof pressure and removal by fire, wind and runoff erosion.

In light of the above information, it is not surprising that the role of trees in the reduction of erosion is regarded as being highly variable, with some trees acting as catchments for soil and others giving rise to rapid soil loss. Trees are not seen as the most important factor in erosion control. Ninety-seven percent of respondents in this survey agreed that trees reduce soil erosion, but Scoones (1990) found that 64% of respondents thought that cattle paths contributed most to erosion, while only 9% cited lack of trees as the major cause.

Soil moisture status

Higher moisture status is commonly found under trees and is most likely due to improved infiltration and lower evaporation losses than in open land (Ingram, 1990). Closed woodlands are able to retain moisture in the humus layer and release it gradually through the year (Pereira et al., 1962). Closed miombo woodland has a higher percentage of moisture than open woodland (Campbell et al., 1988).

Soil nutrient status

Campbell et al. (1988) reported levels of extractable P and N to be significantly higher under closed miombo woodland than open woodland (Table 5). Higher levels of nutrients under canopies compared to between canopies have also been reported by Bosch and van Wyk (1970), Bate (1979) and Olsvig-Whittaker and Morris (1982) for nutrient-poor systems and by Ernst and Tolsma (1989) for nutrient-rich systems. However, higher levels of nutrients are not always reported under the canopies of trees (Griffioen and O'Connor, 1990).

Table 5. Comparison of soil properties between open and closed woodland in a high rainfall region of Zimbabwe (source: Campbell et al., 1988).

	Open woodland	Closed woodland	F (df=1 & 63)	Signifi- cance
Moisture (%)	3.89	8.17	71.0	***
Organic matter (%)	1.62	3.35	17.5	***
Extractable P (mg/100 g DW soil)	0.22	0.99	12.8	***
NO ₃ -N (ug/g DW soil)	0.92	6.16	12.5	***
Nitrification rate (ug NO ₃ -N/g DW soil over a week)	1.0	5.9	18.4	***
n	5	60		

Higher levels of nutrients beneath trees are probably not just the result of increased or maintained litter supply. Trees also improve the nutrient status of soils by maintaining efficient nutrient cycling, by improving the physical structure and moisture holding capacity of the soil so that mineralisation is promoted, by bringing nutrients up the soil profile, by increasing CEC, by fixing nitrogen, by capturing nutrients from the atmosphere and by attracting herbivores whose excreta enrich the soil (Spears, 1986; Georgiadis, 1989; Swift et al., 1989; Ingram, 1990; King and Campbell, in preparation).

Woody plants may make up over 80% of the plant biomass in a community and they contain a greater fraction of the total nutrient pool than grasses and herbs (Swift et al., 1989). While the grass layer has high annual turnover of nutrients, the high proportion of nutrients in the tree layer is relatively static (Swift et al., 1989). Frost (1985) found that grass litter was decomposed twice as fast as tree leaf litter.

Ingram (1990) suggests that efficient nutrient cycling, effected by the capture by tree roots of nutrients in the soil that would otherwise be lost by leaching, is central to explaining why

agroforestry systems can maintain higher soil fertility than simple herbaceous cropping systems. Kellman (1979) attributes the benefits of trees to their prolonged persistence at the one site so that tight nutrient cycles can be established.

Nitrogen-fixation is uncommon in miombo canopy species, probably because extractable P is limiting (Hogberg, 1986). However, about a thousand species of woody legumes (Allen and Allen, 1961), as well as some non-legumes, form nitrogen-fixing nodules. Their potential is realised in alley cropping systems (Kang et al., 1985; Materechera, 1988). *Leucaena leucocephala* has been found to fix $600 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ under favourable conditions (Spears, 1986). This is a maximum figure; more relevant to the drier conditions of Zimbabwe is the $21 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ fixed by *Faidherbia albida* (Felker, 1978), which can be used in mixed intercropping rather than alley cropping.

Negative impacts of trees on soils

Despite the many possible positive impacts of trees on farming systems, these cannot always be guaranteed and there may also be negative impacts. Wilson (1989a) points out that the effects of trees on soil fertility are modified by the amount of rainfall received during the rainy season. Negative effects of trees include competition with crops or grasses for water and nutrients (Knoop and Walker, 1985; Young, 1987), reduction in stream flow, excessive shading of crops, allelopathic inhibition of germination or growth and harbouring of pest populations (Spears, 1986). High levels of nutrients under trees compared to outside the canopy may in some cases be due to depletion of surrounding areas by the laterally extensive root systems of trees (P. Frost, personal communication).

Crop production

Tree-related inputs to crop production in the small-scale farming systems of Zimbabwe come directly from trees left in fields and from transfer of leaf litter from grazing areas to cultivated land. An important indirect input of trees to crop production is via the browse-livestock-manure route (Swift et al., 1989).

A survey in Mutanda Resettlement Area found that 94% of respondents leave selected trees in fields (Grundy et al., in press); indigenous trees remain a distinctive feature of most cultivated areas in Zimbabwe (Wilson, 1989a; Campbell et al., 1991). Although maintenance of soil fertility is not the primary reason for the retention of trees in fields (Grundy et al., in press; Wilson, 1989a), farmers recognise the positive effects of certain trees on

crop yields and in some cases restrict the use of fertilisers under the canopy (Abel et al., 1989; Wilson, 1989a; Ingram, 1989). In the current survey 53% of respondents replied "yes" to the question, "Does having some types of trees scattered in your fields improve your crop yields?" Species recognised as improving crop yields include *Parinari curatellifolia*, *Ficus capensis*, *F. burkei* (Arnold, 1991), *F. sur*, *F. sycamorus* (Ingram, 1990), *Lonchocarpus capassa* and *Rigelia africana* (Wilson, 1989a).

In Shurugwi, Zimbabwe, Abel et al. (1989) found that maize cob volume was significantly higher under tree canopies than outside canopies in unfertilised fields (Table 6). It was not ascertained whether this represented a higher yield per unit area of the field.

Table 6. Mean maize cob volume (cm^3) under and away from tree canopies in relation to fertility management (source: Abel et al., 1989).

	Under tree canopy	Outside canopy
Fertilised fields*	118.2	117.8
Unfertilised fields	100.0	23.5

*includes inorganic fertiliser, manure and termitaria.

The use of nitrogen-fixing trees may have great potential in Zimbabwe. Under *Faidherbia albida* individuals, *Pennisetum* millet is found to have 2.5 times the yield and 3.5 times the protein yield as that grown in the open (Charreau and Vidal, 1965). Overall, fields containing *F. albida* give millet yields of 2-2.5 times those of open fields (de Montgolfier-Kouevi and le Houerou, 1980). The trees also provide 200-600 $\text{kg ha}^{-1} \text{yr}^{-1}$ of protein-rich pods that can be fed to livestock. A century ago, the Sultan of Zinder in Niger decreed that anyone cutting down an *F. albida* would himself be decapitated (de Montgolfier-Kouevi and le Houerou, 1980). *F. albida* is native to Zimbabwe and is used in cultivation by the Tonga people of the semi-arid Zambezi Valley (Clarke, 1983). A more formalised use of nitrogen-fixing trees is in alley cropping, in which trees are grown to maintain high crop yields (Kang et al., 1985; Materechera, 1988) and reduce leaching rates to those of natural or artificial forest ecosystems (Imbach et al., 1989). Alley-cropping experiments were begun in Zimbabwe in 1986 (B. Maasdorp, personal communication).

The majority of traditional farming systems in Zambia, for

example the chitemene shifting cultivation system, utilise bush fallow to improve soil fertility, while at the same time producing useful by-products, such as construction wood, fuelwood and animal feed (Lawton, 1982; Chidumayo, 1988). In Zimbabwe, the use of bush fallow is uncommon at present, though it is practised in the high rainfall Honde Valley (Campbell et al., 1991).

In Zimbabwean small-scale farming systems, the major nutrient transfers from grazing areas to cultivated areas are in the form of manure, soil from termitaria and leaf litter (Swift et al., 1989). This survey found that 68% of respondents brought leaf litter to fields to improve soil fertility. The practice was found to be more common in higher rainfall areas. The figure is considerably higher than the 32% reported by Grundy et al. (in press) for Mutanda Resettlement Area and the 38% reported by Balderrama et al. (1988) for Chivi South.

Livestock production

Sixty-four percent of respondents in the current survey replied "yes" to the question, "Does having trees make it possible to keep a greater number of cattle?" Small-scale farmers have in the past been reluctant to cooperate with government attempts to initiate bush clearance programmes (Scoones, 1990). One farmer is quoted as saying, "In this region the cutting of trees will be no good. The livestock rely heavily on trees here. They are important in the dry season and in droughts" (Scoones, 1990). Trees are important to livestock in two senses: directly, through the provision of browse and indirectly, through their influence on grass quality and quantity.

Browse

The forage value of any plant is the result of two main factors: its palatability to livestock and its nutritive value (le Houerou, 1980). Miombo-type woodland produces 0.7-1.2 tonnes ha⁻¹ dry matter annually and Acacia-type woodland produces 668 kg ha⁻¹ yr⁻¹ (Spears, 1986), but such yields may not translate into browse yields. For instance, a yield of 1.7 tonnes ha⁻¹ in Cameroon produces 120 kg ha⁻¹ fodder because upper branches are inaccessible and few tree species are palatable (Spears, 1986). In Zimbabwe, browse at 300 kg ha⁻¹ dry matter was measured at Matopos during the rainy season (Gambiza, unpublished results). The crude protein digestibility of common browse species in southern Zimbabwe is high (Barnes, 1979) and, in general, the crude protein content of browse is higher than that of grasses at all times of the year, except the early growing season (Weinmann, 1948; West, 1950; le Houerou, 1980; Dube, in press).

Browse is particularly important in the dry season. Spears (1986) estimates that 20% of livestock feed in tropical Africa is provided by browse, rising to 30% in the dry season in drier areas. In the dry season in southern Zimbabwe, Scoones (1990) found that cattle spent 50-60% of their feeding time browsing, mainly on leaf litter (Figure 7). Similarly, on the red soil thornveld of Matopos, goats spent 60% of their feeding time browsing during the dry season compared to 47% in the wet season (Sibanda, in press). Woody vegetation breaks dormancy to produce the new season's flush of leaves usually from August to October, well before grass growth begins, thus providing a high quality food source in the late dry season when grass is scarce (Walker, 1980). This period also coincides with late pregnancy in most ungulates. At this time, some farmers will lop branches to give to livestock as feed (Scoones, 1990). In any one type of woodland, a few tree species are found to be vital for browse, for example *Colophospermum mopane* on southern Zimbabwean clay veld (Scoones, 1990).

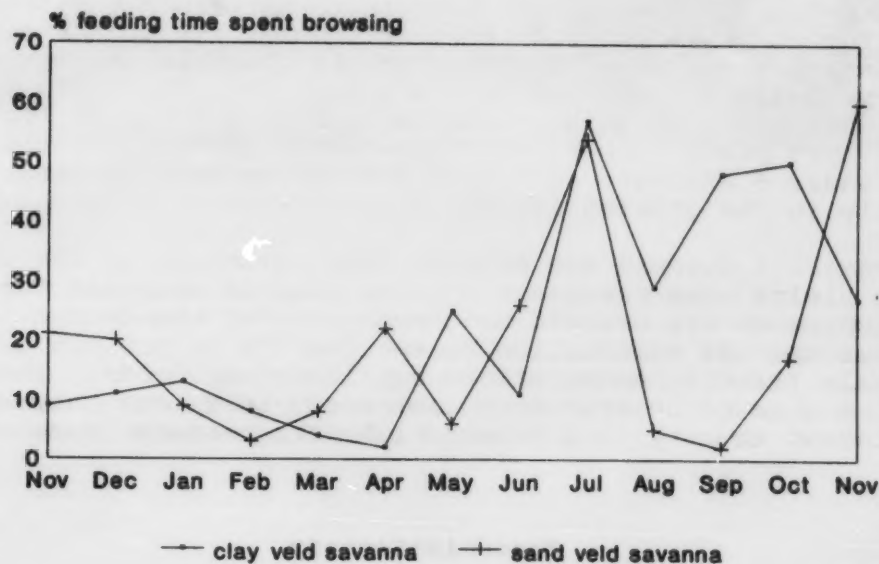


Figure 7. Percentage of feeding time spent browsing in sand veld and clay veld cattle herds in a semi-arid region of southern Zimbabwe (source: Scoones, 1990).

Browse biomass varies less than grass biomass inter-seasonally (Walker, 1980). Trees can provide livestock fodder in drought years when grass cover fails and, because they cannot be completely consumed, provide a minimum plant reserve for subsequent recovery (Walker, 1980). Thus trees act as a nutrient reservoir largely inaccessible to herbivores and fire (Swift et al., 1989).

Effects on grass

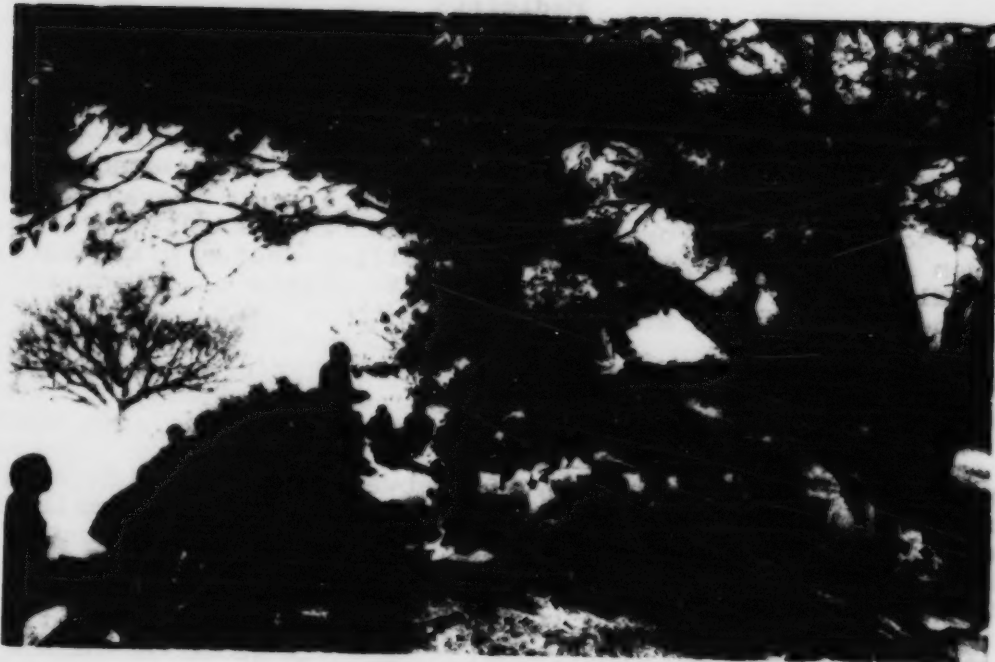
Most studies find increased grass yields on plots cleared of trees compared to uncleared plots (Dye and Spear, 1982; Gammon, 1983). Barnes (1979) found that clearing trees led to an increase in grass yield of between 134% and 443%. Frost (personal communication) found increases of up to 1100% in relatively dry years. Some studies find higher grass yields under individual trees, such as *Acacia karroo* (Stuart-Hill et al., 1987) but these may be unimportant on a regional basis. Georgiadis (1989) found that grass production was 42.3 g m⁻² under *Sericocomposis pallida* compared to 14.0 g m⁻² in the open, but at average tree density this represented an increase in grass productivity of only 2% on a regional scale.

Although clearing of trees from grazing areas can lead to dramatic increases in standing herbaceous biomass, the increase in livestock production is much smaller (Plowes, 1956). This discrepancy is attributed to a change in the herbaceous species composition to less palatable species. For example, Barnes (1979) found that clearing trees led to decreases in palatable grasses such as *Panicum maximum*, *Urochloa* spp. and *Digitaria* spp. Grossman et al. (1980) found that, in *Burkea* savanna, higher peak grass biomass was found in open plots compared to those under *Burkea africana*, but the grasses under *B. africana* contained greater amounts of crude protein, especially in the growing season.

Commercial farmers are able to take advantage of the increase in grass yields when trees are removed because they can feed their cattle supplementary protein to compensate for the change in herbaceous species composition to species low in protein. Small-scale farmers cannot afford supplementary feeds. Thus they may not be able to benefit from increased yields and they will have more interest in retaining trees (P. Frost, personal communication).

Trees in Society

Trees act as landmarks, meeting places and play facilities for children. In the survey 58% of respondents said that they used trees to mark the boundaries of fields and 74% said that it was important to have trees around their houses or in the bush for their children to play in.



Trees are popular meeting places.

Some trees are sacred (Wilson, 1989a; Grundy 1990). Sixty-four percent of respondents said that trees were important to the spiritual well-being of their household. There are taboos on cutting certain trees in fields, since tradition holds that these are a resource owned by the community at large (present and future) and particular trees are linked to ancestral spirits (Wilson, 1989a).

Shade

Trees provide shade for animals and people in grazing areas, fields and homesteads. Trees are left in fields to provide shade for workers (Wilson, 1989a; Grundy et al., in press) and around the homestead shade trees are sometimes planted (du Toit et al., 1984). The current survey found that 66% of respondents planted trees for shade (Figure 3).

Medicines

Approximately 500 species, 10% of Zimbabwe's flora, including many tree species, are used medicinally by traditional healers. Traditional healers have an important role in both rural and urban communities, providing advice, divination and herbal prescriptions for physical and psychological complaints. Tree-derived medicines are most commonly taken orally in the form of an infusion, often made from roots. Traditional healers collect useful plant material from woodlands and are known to travel far afield in search of prized species (Gelfand et al., 1985).

Cash Income

Markets for tree products in Zimbabwe are very small (Bradley and McNamara, 1990). In Communal Areas, people will generally go without products that they cannot afford to buy (Bradley and McNamara, 1990). The extent of sale is further limited by transport and storage difficulties (Gumbo et al., 1990) and social restrictions on the sale of some tree products, such as fruits (Wilson, 1989a; Gumbo et al., 1990). Even though markets are limited, a wide variety of products are sold, the most frequent being fruits and crafts (Figure 6). Households selling exotic fruits can expect to earn on average \$46 yr⁻¹ (SD: 20.8, n = 20, questionnaire III), while those selling indigenous fruits can expect on average \$20 yr⁻¹ (SD: 5.7, n = 5, questionnaire III).

Craft workers in Mangwende earned between \$3 and \$200 per year, averaging \$53 yr⁻¹ (SD: 56.7, n = 10, questionnaire III). In Binga District there are about 1000 producers of crafts and they sell roughly 75% of their crafts through the Binga Tonga Craft Center (J. Kristenson, personal communication). The Centre paid out over \$99 000 for crafts supplied to it in 1990, which means that producer households received roughly \$130 each. Urban markets are supplied to some extent by products from small-scale farms, but these markets too are small. For example, even in areas close to cities there is not a well developed market in fuelwood between Communal Areas and urban dwellers. Most fuelwood used in cities is indigenous, but almost all of it is derived from large-scale commercial farms (Attwell et al., 1989).

Chambers (1988) argues that trees represent monetary security in times of stress. There is very little information to support such a contention in Zimbabwe, though Mazambani (1984) indicates that more wood for urban Harare comes from Communal Areas in times of drought, implying that when there are poor harvests, small-scale farmers resort to selling wood.

CHAPTER THREE: VALUATION OF GOODS DERIVED FROM TREES

Introduction

We attempt to give a monetary value to the goods that trees provide. The economic valuation is crude by necessity: neither the available data nor the situation allow for accurate economic accounting. The estimated value is calculated simply from a knowledge of the quantity of goods derived from trees multiplied by the "farm gate prices" of these goods or the "replacement cost". By using "farm gate price" of a subsistence product, we assign value on the basis of exchange value. "Replacement cost" is the cost a producer would have to pay to replace the subsistence product. Because of the use of "farm gate price" or "replacement cost" for goods which, in fact, are mostly not bought and sold, there is an overestimate of local use value, as: (i) in most cases, the financial constraints facing small-scale farmers do not permit them to switch to a marketed product; (ii) small-scale farmers would probably not choose to buy the marketed replacement if the necessary financing were made available to them unconditionally; and (iii) the prices used do not take into account 'diminishing marginal utility' (if all the *Strychnos* fruits were taken to the market place, the price per fruit would drop dramatically). At this stage it is not possible to undertake full cost-benefit analysis, due to paucity of data, particularly labour inputs. In our analysis, we assume that woodland has no intrinsic value and all benefit is appropriated by labour, whether the product is consumed or sold. The purpose of the analysis is not to give precise figures, but to give comparative values for different goods provided by trees.

Fruit

Strychnos cocculoides, for which we have some data, can be taken as an example of a commonly used fruit tree in Zimbabwe. A single tree produces a mean of 34 fruits yr^{-1} (Campbell, unpublished data) which can be sold at 5 cents a fruit (questionnaire II; Gumbo et al., 1990), thus giving products worth \$1.70 yr^{-1} per tree. Species of fruit tree differ in productivity, marketability and nutritional value and each species ought to be valued separately.

Owing to the limited data on indigenous fruit production and market prices, we have to make the unrealistic assumption of equivalence of value between *Strychnos* and other wild fruit trees. This assumption is probably close to the truth for fruit trees in cultivated fields, where only valuable fruit tree species are preserved, but is less likely to be the case in woodlands, where a wide range of species can be found (Campbell, 1987). We also have to assume that all fruits are indeed consumed by a household, rather than being eaten by birds, mammals or insects or being left to rot. There are no data on which we can test the validity of this assumption.

In fields in the Save area, fruit trees occur at a density of about 7.3 trees ha^{-1} ($n = 12$) in one of the two recognised types of fields and 8.6 trees ha^{-1} ($n = 7$) in the other (raw data from Campbell and du Toit, in press). In the Mutanda Resettlement area in the same region, fields have an average of 2 trees ha^{-1} (SD: 0.8, $n = 4$, raw data from Grundy et al., in press). Thus trees in fields produce products valued at from \$3 $\text{ha}^{-1} \text{yr}^{-1}$ to \$15 $\text{ha}^{-1} \text{yr}^{-1}$ or, assuming households have on average 3 ha of fields (Bratton, 1987; Reh et al., 1988), the household receives fruits which value between \$10 $\text{hh}^{-1} \text{yr}^{-1}$ to \$44 $\text{hh}^{-1} \text{yr}^{-1}$ (throughout the work the abbreviation "hh" refers to household). Figure 10 shows the derived value for each of the categories of goods.

In natural woodlands in Mutanda, fruit trees are very common, averaging 82 trees ha^{-1} (SD: 75.5, $n = 15$ plots, raw data from Grundy et al., in press). Thus natural woodlands produce fruit to the value of about \$139 $\text{ha}^{-1} \text{yr}^{-1}$. However, woodlands in Communal Areas are seldom in such good condition and the number of fruit trees is usually lower. For instance, in the Save area, the miombo woodland and its derived community-types has on average 38 fruit trees ha^{-1} ($n = 58$ plots, raw data from Campbell and du Toit, in press), giving a total value of about \$65 $\text{ha}^{-1} \text{yr}^{-1}$.

In order to value the fruit tree resource from the perspective of the household, it is necessary to know the amount of fruits used by each household. These data are not available. If we calculate 1991 population densities predicted from the 1982 census (see Bradley and McNamara, 1990) and calculate the area available to the population for grazing, then we can calculate the average area available to each household, which ranges from about 3.5 $\text{ha}^{-1} \text{hh}^{-1}$ to 5.6 $\text{ha}^{-1} \text{hh}^{-1}$ in the three study areas of Questionnaire I. Using these figures and the valuation of \$65 $\text{ha}^{-1} \text{yr}^{-1}$, the fruit tree resource in woodland and its derivatives produce to the value of \$230 $\text{hh}^{-1} \text{yr}^{-1}$ to \$360 $\text{hh}^{-1} \text{yr}^{-1}$. Unfortunately, these figures do not take into account any measure of accessibility (many grazing areas are far from village areas and thus fruits are less likely to be consumed).

The paucity of data also makes it difficult to value exotic

fruit trees around the homestead. Using production figures from local knowledge and Purseglove (1968), estimates of fruit tree holdings (Campbell, 1987; Reh et al., 1988) and prices of fruits in rural markets (this survey; Gumbo et al., 1990), the value of production is about \$12 $\text{hh}^{-1} \text{yr}^{-1}$.

Other Wild Foods

From the data on amounts consumed (Table 3), the percentage of households consuming wild foods (Figure 2) and the price of wild foods (Table 3), the total value of wild foods consumed is only about \$63 $\text{hh}^{-1} \text{yr}^{-1}$.

Fuelwood

Assuming that a household uses 6.5 tonnes yr^{-1} of fuelwood (Grundy et al., in press) at a cost in rural areas of \$28 per tonne (SD: 10.1, $n = 17$, questionnaire III), fuelwood is worth about \$182 $\text{hh}^{-1} \text{yr}^{-1}$. Additional fuelwood costs come from the firing of bricks. Although about 2.05 tonnes of fuelwood is required per house (Grundy et al., in press), one house lasts 25 years (Grundy et al., in press) and only 46% of households own a brick house (Questionnaire I, $n = 359$) so that only about \$1 is added to the fuelwood value, giving a total value of \$183 $\text{hh}^{-1} \text{yr}^{-1}$. However, this value of wood for brick houses does not take into account the rapid increase in numbers of brick houses, i.e. additions to the existing stock of houses.

Construction Wood

Using rural purchase prices of \$57 per tonne for timber (SD: 34.5, $n = 24$, questionnaire III) and the consumption figure for timber of 2 tonnes $\text{hh}^{-1} \text{yr}^{-1}$ (Grundy et al., in press), the value of construction wood from woodlands is about \$114 $\text{hh}^{-1} \text{yr}^{-1}$.

On the basis of the information on ownership of wood-derived utensils and implements, and the durability and price of these (Table 4), it can be calculated that implements and utensils derived from local woodlands have a value of about \$16 $\text{hh}^{-1} \text{yr}^{-1}$, with implement handles contributing the most value.

Also to be included is the value of materials for craft work. Considering that 14% of households sell craft (questionnaire I) and that average earnings range between \$53 (Mangwende) and \$130

(Binga), the value of materials for crafts averaged over all households is roughly \$7 $\text{hh}^{-1} \text{yr}^{-1}$ to \$18 $\text{hh}^{-1} \text{yr}^{-1}$.



Raised huts use about 2.5 m^3 of straight poles, with over 200 poles per hut.

Crop production

The effects of trees on crop production in Zimbabwe are not well documented. However, we attempt an evaluation based on the inputs of trees to soil fertility. Using the ICRAF SCUAF model (Young and Muraya, 1990) with inputs relevant to agro-ecosystems in the miombo areas of Zimbabwe (Campbell et al, 1988; Swift et al, 1989), the few scattered trees in Zimbabwean fields are found to add about 9 $\text{kg ha}^{-1} \text{N}$ over 15 years compared to fields where trees are absent. Calculating the fertiliser equivalents of this addition and using the price of fertiliser in the Communal Areas (\$33 for a 50 kg bag of Compound D in 1991), scattered trees in fields contribute about \$15 $\text{hh}^{-1} \text{yr}^{-1}$ to soil fertility if each household has 3 ha of cultivated land (Bratton, 1987; Reh et al., 1988). However, no information is as yet available on the degree to which the nitrogen added by scattered trees is reflected in higher crop production, as negative effects such as shading must be considered. Assuming that there is some cost would mean that the value of trees scattered in fields for soil fertility is very low.

Assuming that a household using leaf litter uses 3.0 tonnes yr^{-1} (P. Nyathi, personal communication), that leaf litter contains approximately 1.35% N on a dry weight basis (Campbell et al., 1988) and that 40% of households use leaf litter (this survey; Balderrama et al., 1988; Grundy et al., in press), leaf litter has a value of about \$134 $\text{hh}^{-1} \text{yr}^{-1}$ averaged over all households.

Livestock Production

Only a few workers have attempted to quantify the relationship between livestock production and browse (e.g. Plowes, 1956; Kennan, 1969; Aucamp et al., 1983, cited by Stuart-Hill, 1987). The main reason for this is the difficulty in determining both browse intake under field conditions (Wilson, 1969; Barnes, 1976) and browse primary production (Rutherford, 1979; Milton, 1983). It is well established that the amount of browsing by herbivores varies with season, availability of herbage and species of animal. Therefore, specific calculations on the actual value of browse in livestock production is a formidable task. Stuart-Hill (1987) showed that the relationship between tree density and herbaceous biomass is not linear (Figure 8). Livemass production (cattle plus goats) in the False Thornveld of the Eastern Cape was highest at 1320 tree equivalents per hectare (Figure 9). Gross margin was highest at 1000 tree equivalents per hectare.

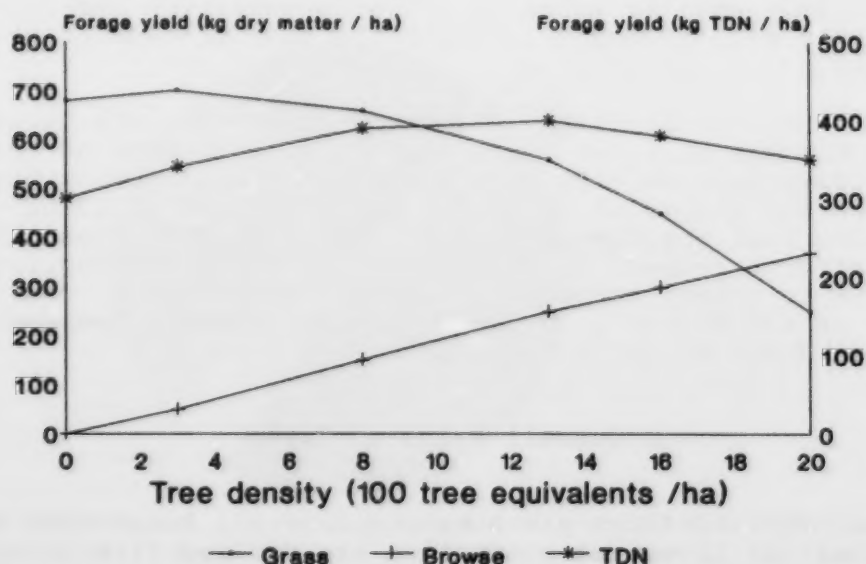


Figure 8. The influence of *Acacia karroo* density on grass, browse and digestible nutrients (source: Stuart-Hill, 1987).

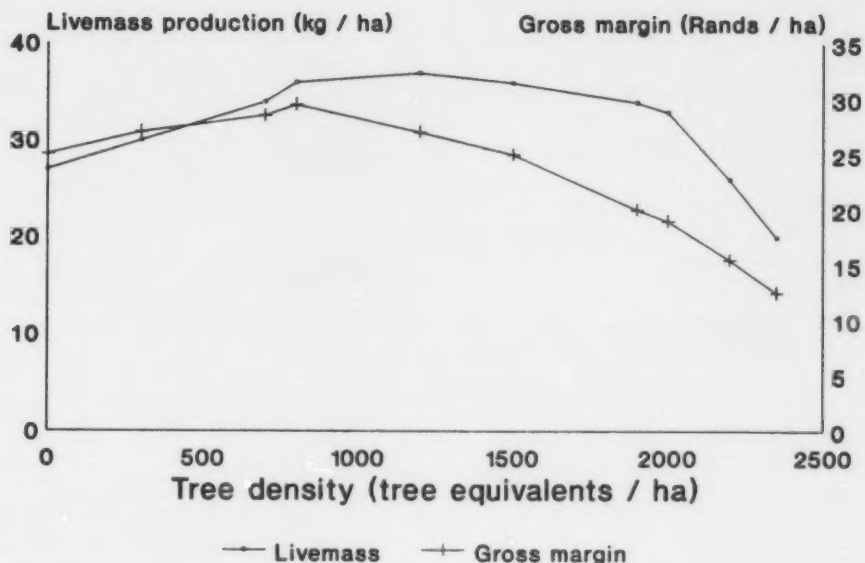


Figure 9. The influence of *Acacia karroo* density on combined (goats plus cattle) livemass production and gross margin (source: Stuart-Hill, 1987).

Where grass production is low, such as in high use Communal Areas and during periods of drought, browse becomes very important (Scoones, 1990) and its value as a highly nutritive and dependable fodder supply will probably outweigh the cost of reduced grass cover under trees.

Stuart-Hill et al.'s (1987) data suggest that the amount of livestock biomass that can be carried in an area with no trees is over 25% lower than an area with scattered trees. Using Scoones's (1990) data for the value of livestock in Mazhiva (\$113 ha⁻¹ yr⁻¹) and assuming that the Communal Areas have tree densities close to the optimal with respect to Stuart-Hill et al.'s findings, the extra benefit due to trees, compared to areas without trees, could be in the order of \$30 ha⁻¹ yr⁻¹, or, on a household basis, between \$100 hh⁻¹ yr⁻¹ and \$160 hh⁻¹ yr⁻¹.

Overall Value of Trees

Values derived above are averaged over all households and all except those for livestock production are derived from miombo systems. If we assume that the value of trees for livestock production would be the same in a miombo system, we can sum the values. Natural miombo woodland therefore produces goods to the

value of about $\$200 \text{ ha}^{-1} \text{ yr}^{-1}$, while scattered trees in fields value at about $\$15 \text{ ha}^{-1} \text{ yr}^{-1}$. In total, trees produce goods to a value of nearly $\$1000 \text{ hh}^{-1} \text{ yr}^{-1}$.

Our valuation is based on the amount and price of goods obtained from trees and woodlands by households, except in the case of fruit, where production data have been used. If current demand is in excess of sustainable levels of production, the values we obtain, especially for fuelwood and construction wood, do not account for environmental degradation as a result of non-sustainable use. Generally, if progressive decline of the woodlands is occurring, the key issue is likely to be the future effects rather than current value as determined here.

Milton and Bond (1986) found that thorn tree savanna is worth about the same as we have found for miombo woodland, but the relative values of various functions are different. Although wood for construction and fuel make up a high percentage of the total value found for miombo woodland, as important, if not more so, are wild fruits, browse and the litter inputs for cultivated fields (Figure 10). Building wood is more or less as valuable as fuelwood even though the quantities consumed of the latter are much higher. Whereas Milton and Bond (1986), investigating *Acacia* woodland which is not used much for construction, found that less than 10% of the total value is due to construction wood and over 50% to fuelwood, we found the ratio of building wood value to fuelwood value to be approximately 2:3.

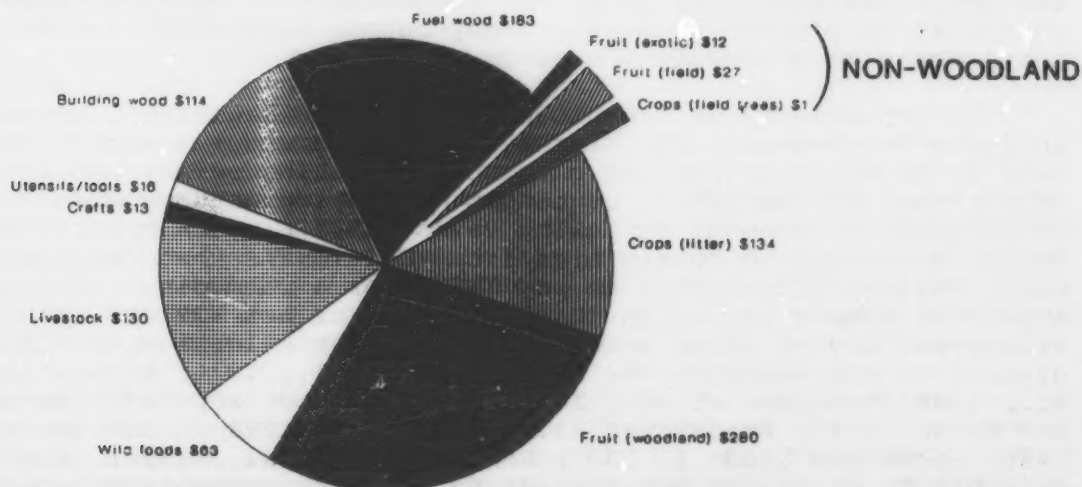


Figure 10. The value of various woodland products (Z\$ per household per annum). For values derived as a range in the text, the mid-point of the range has been used.

CHAPTER FOUR: CONTINGENT VALUATION

Introduction

Organised markets are a major mechanism for identifying the values and preferences of individuals and society and hence in guiding their consumption and investment decisions. Apart from the obvious case where commodities are not traded in organised markets, markets do not necessarily reflect the true preferences or values of society where the property rights governing access to resources are non-exclusive (Randall, 1983). Access to tree resources in the smallholder sector are governed by a mixture of private and *res communis* property rights (Wilson, 1989a); they are resources that have rights of exclusion operating at the level of the individual and at the level of the community. Many of the commodities that trees provide are not traded in organised markets (e.g. browse, erosion control) or may be non-rival (i.e. their consumption by one individual does not reduce the availability for another, for example the spiritual aspect of trees) or congestible goods (i.e. they are non-rival to a point whereafter they become congested; for example, shade would be a congestible good).

In the absence of organised markets, an intuitively appealing approach to revealing the preferences of individuals and society (and in so doing to provide guidance in setting policy and research objectives) is the use of contingent valuation methods (CVM). These techniques, in general following Davis (1963), use a hypothetical market situation to obtain bids from individuals that represent their maximum willingness to pay (WTP) for a commodity. Despite the appeal of simply asking an individual his or her WTP and the widespread use of these methods for resource valuation (for further discussion and examples see Brookshire et al., 1976; Brookshire et al., 1980; Schultze et al., 1981; Brookshire et al., 1983; Mendelsohn and Brown, 1983; Randall et al., 1983; MEWRD, 1985; Cummings et al., 1986; Hoehn and Randall, 1987; Whittington et al., 1990), the reliability of values obtained using CVM is vigorously debated (Bishop and Heberlein, 1979; Bishop et al., 1983; Knetsch and Sinden, 1984; Brookshire and Coursey, 1987; Mitchell and Carson, 1989). The acceptability of the values obtained using CVM is likely to depend a) on the variance or reliability of the estimate and b) the validity or the degree to which the estimate measures the

theoretical construct under investigation (Mitchell and Carson, 1989; Reiling et al., 1990).

This section describes the use of a CVM to elicit the preferences of Zimbabwean smallholder farmers for the commodities they obtain from trees. The method, as well as tests for validity and reliability are described in detail as this is one of the first attempts to apply CVM to value common access resources in the smallholder sector of Zimbabwe. The results of the study are discussed with regard to their implications for policy and research.

Methods

Questionnaire design

The value of each category of tree commodities was derived from information provided by respondents in two separate sections of Questionnaire I.

In the first section of the questionnaire a hypothetical/indirect method (Mitchell and Carson, 1989, p81) of eliciting values was used. An adaptation of the scoring method, described by Sinden and Worrell (1979, p206), was used to obtain scores for the relative preferences of respondents for each category of tree commodity: ten cards, each pictorially representing one of the ten commodity categories (animal feed, building and household materials, fuel, food, cash income, inputs to crop production, shade, social aspects, health and ecological functions) were laid out before, and carefully explained to each respondent. Two cards representing commodities not related to trees were included to "anchor" the preference scoring; one showing a hand borehole (a "bush pump") and one showing a well-known design of toilet (Blair toilet; Blair Research Laboratory, 1989). Respondents were first asked to rank the cards to reflect the relative importance of each category of commodities. The enumerator noted the rank order and then gave respondents fifty matches and asked him or her to distribute these among the cards to reflect the relative importance of each category of commodities.

In the second section of the questionnaire three questions were asked of the respondent. For the first question the enumerator read a description of a hypothetical scenario to the respondent. In this scenario the respondent was offered the (hypothetical) opportunity to join four other households and sink a borehole and install a hand pump. It was explained that the participating households would be guaranteed finding water, that they would have exclusive use of the borehole and that they would be able to obtain an interest-free loan to pay for their share of the borehole with repayments to be made

over five years. The money would be deducted directly from money they would receive from crop sales to government marketing agencies. Respondents were then asked to state what they would be willing to pay for their share of the borehole. These responses provided the willingness to pay (WTP) results used in subsequent analyses.



A borehole was used to anchor the preference scoring in the contingent analysis.

In the second question of this section, respondents were asked what compensation they would be prepared to accept from the government if the government were to destroy the borehole (in order to complete a construction project) they shared with four other households. Responses to this question yielded the willingness to accept compensation (WTA) results used in the validity checks. This scenario was also read to respondents to ensure consistency in the presentation of the hypothetical situation.

In the third question of this section of the questionnaire a series of dichotomous choice (DC) questions were asked. The respondent was asked to choose between having a borehole shared with four other households and a series of five commodities decreasing in value from about Z\$35000 to about Z\$90.

In the last section of the questionnaire background information

that would be used to check expected relationships were collected. These data included details on the respondent (sex, age, years resident in area, years education), on the household (number of people, major crops grown, number of cattle and goats owned, ownership of assets, house type) and on the nature of household water supplies.

In addition to the household questionnaire, a very similar questionnaire was mailed to government officials at local level, district level and provincial level in the areas where the household questionnaire was conducted. This questionnaire did not include questions on valuing a borehole. In total 72 questionnaires were mailed and 39 returned. Officials covered included those in Forestry Commission, Natural Resources, Agricultural Extension, Veterinary Services and Local Government. Also covered by this survey were professionals in central government in the above institutions and university academics.

Calculations and analysis

Points allocated to each category of tree goods and services were standardised against the points allocated to the borehole. Each category of commodities as well as the Blair toilet were therefore converted to units of "borehole equivalents". These units were multiplied by the total value of the borehole implied from the respondent's expressed willingness to pay (WTP) for her or his share of the borehole (i.e. the borehole value = 5 * stated WTP). To normalise their distributions the values data were log transformed for analysis. All means presented in the body of the section are geometric means.

A series of validity and reliability checks were carried out (Appendix 1). These provided reasonable grounds for accepting the validity of survey results.

Results

Overall values

Mean values (Z\$) for tree-derived commodities are presented in Figure 11. The tree commodity categories appear to fit into three groups of importance: in the first group are the direct inputs to households (fuel and farm and household materials). In the second group are the inputs to production activities (crop inputs, animal feed and cash income) whilst the third group comprises most of the tree-related services (ecological services, shade, health, social services). Whilst there is obvious overlap among these groups these trends can be followed through the ensuing discussion. In general

the groups as described appear to show that direct material inputs and inputs to major productive practices are the most valuable categories of commodities that households obtain from tree resources.

If we assume a discount rate of between 5 and 20% and convert the above capital value of resources to an annual benefit stream (using $A = C * i$, where A is the annual benefit stream, C is the capital value and i the discount rate), then the annual benefits derived from tree resources could amount to between Z\$84 and Z\$336 per household per year.

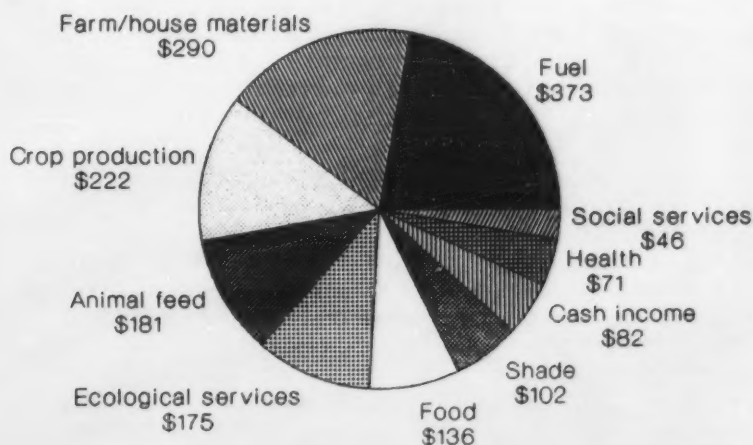


Figure 11. Mean values (Z\$) for categories of commodities provided by trees. Values calculated from stated WTP for a fifth share in a borehole.

Values in relation to income

To establish the relative importance of these values and those presented in Figure 11 they need to be viewed in the context of average annual incomes in the smallholder sector. The most recent household income data available for comparison are those for Mutoko/Mudzi (Natural Region IV) and Buhera (Natural Region V) for the 1988/89 season (Mudimu et al., 1989). Older data, but collected in two of the areas used in the present study (Mangwende and Chivi) are presented in the Farming Systems Research Unit annual report for 1983/84 and are credited to Shumba (1984) and CIMMYT (1982). Mean annual incomes from these studies and the capitalised values of these income streams at four discount rates are presented in Table 7.

The annualised benefit streams that the average smallholder

householder derives from tree resources are equivalent to between 40 and 160% of off-farm and agricultural production incomes in Chivi and between 12 and 47% of off-farm and agricultural production incomes in Mangwende. Tree resources thus make a significant contribution to the livelihood of smallholder farmers and appear to do so particularly in the low production area Chivi.

Table 7. Average annual incomes and annual incomes capitalized at four discount rates for Mutoko/Mudzi, Buhera, Chivi and Mangwende communal areas. All values converted to 1989/90 dollars using a 2% inflation rate.

Region	Average Annual Income (Z\$)	Capitalized mean annual incomes at interest rates of:			
		5%	10%	15%	20%
Mutoko / Mudzi	146 ^a	2920	1460	973	730
Buhera	159 ^a	3180	1590	1060	795
Chivi	207 ^b	4140	2070	1380	1035
Mangwende	717 ^b	14340	7170	4780	3585

a. Source Mudimu et al., 1990. Data for 1988/89 season.

b. Source CIMMYT, 1982; Shumba, 1984. Chivi data for 1980/81 season, Mangwende data from 1981/82 season.

Values in relation to interventions

A clearer appreciation of the values held by smallholder farmers will facilitate greater understanding of their behavior with regards to resource consumption and technology adoption. For example, the value of fuelwood shown in Figure 11 (Z\$373) implies annual benefits of Z\$37 per household per year (assuming an arbitrarily chosen 10% interest rate). Smallholder farmers could therefore be expected to be willing to pay (in cash or labour equivalents) up to Z\$37 per year to secure fuelwood supplies. With eucalyptus wood costing between Z\$32 and Z\$40 per ton to produce (Coopers and Lybrand, 1986) and the average household requiring about 5.5 tonnes of fuelwood per year (Grundy et. al., in press), simple arithmetic will show that it seems unlikely that households in areas such as those surveyed would invest in eucalypt plantations for fuelwood. Similar calculations can be carried out for other commodities for which reliable data exist. These calculations are

only instructive in defining research priorities as the results clearly depend on the interest rate chosen.

Values in relation to site and tree cover

Patterns of importance for the tree commodity categories differ notably among the three study areas (Table 8). The most notable difference is the high rank of the cash category in Mangwende compared to the other areas. This difference is to be expected as farmers in Mangwende, being a high potential area, are likely to be constrained by cash and capital rather than the productive capabilities of the environment. Due to its proximity to the large urban markets in Harare, Mangwende also offers opportunities for trade which are unlikely to be feasible in the other two areas. In the lower rainfall areas however, the environment would be the most binding constraint on production. The relatively low ranking of ecological properties in Shurugwi is also notable.

Table 8. Mean, 95% confidence intervals of points allocated to tree commodity categories and ranks (by points allocated) for Mangwende (n=111), Shurugwi (n=123) and Chivi (n=124). Means are based on untransformed data.

Category	Mangwende		Shurugwi		Chivi	
	Mean points	Rank	Mean points	Rank	Mean points	Rank
		n		n		n
		k		k		k
Fuel	5.4	1	5.4	1	5.4	2
Material	4.7	2	4.9	2	5.6	1
Ecology	4.3	3	3.2	6	4.5	4
Crop	3.7	4	4.3	3	4.7	3
Cash	3.5	5	1.9	10	2.1	9
Animal	3.4	6	3.5	4	3.5	5
Food	2.8	7	3.3	5	2.9	6
Shade	2.5	8	2.1	8	2.8	7
Social	2.3	9	1.9	9	1.6	10
Health	2.2	10	2.2	7	2.1	8

The relationship between tree cover and the values derived for tree resources are presented in Figure 12. As is to be expected, total tree resource values were higher in the low tree cover areas than in the high tree cover areas. Values derived for fuelwood, household and farm materials, crop inputs, animal feed and ecological properties were significantly higher in the low tree cover areas. These results indicate the relative scarcities of tree resource commodities and how these are valued by households. The commodities that are more highly valued in the low tree cover areas are those towards which research efforts should be directed. The differences between mean values of those commodities that are significantly different are indicative of the costs of changing from a high to a low state of access to the particular commodity in question. For example, to increase the availability of tree resources from a low to a high state would yield added benefits to the average household of about Z\$228 for materials, Z\$173 for fuel, Z\$122 for crop inputs, Z\$110 for ecological properties and Z\$91 for animal feed. These added benefits provide clear indicators of where research should be focused as the gross returns to investment in tree resources are likely to parallel these added benefits. It remains for researchers to develop technologies that will provide these returns at costs lower than their current value to the householder.

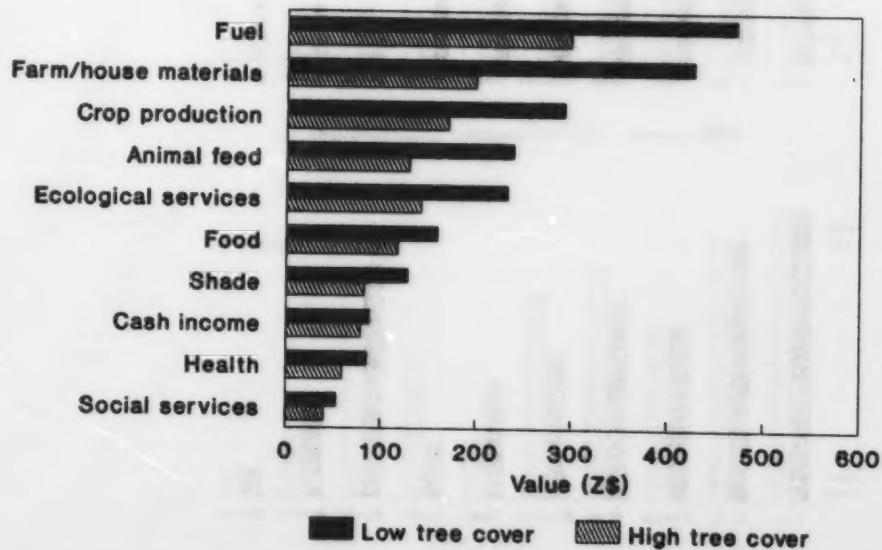


Figure 12. Mean values (Z\$) for categories of commodities provided by trees as related to tree cover.

In Figure 13 the relative rankings given to tree commodity categories by experts and field professionals for Natural regions II and III and regions IV and V are shown in relation to the rankings of householders.

Values of "experts"

The "experts", in their role of identifying societal values rank and value categories of commodities for the two groupings of natural region, in ways that do not match the rankings of the smallholder farmers. Both smallholders and experts recognise the primary importance of fuel and household or building materials. The most notable differences between the values of smallholders and society (represented by the experts) were the high importance assigned to food, cash income and social categories by experts and the very low value they assign to shade.

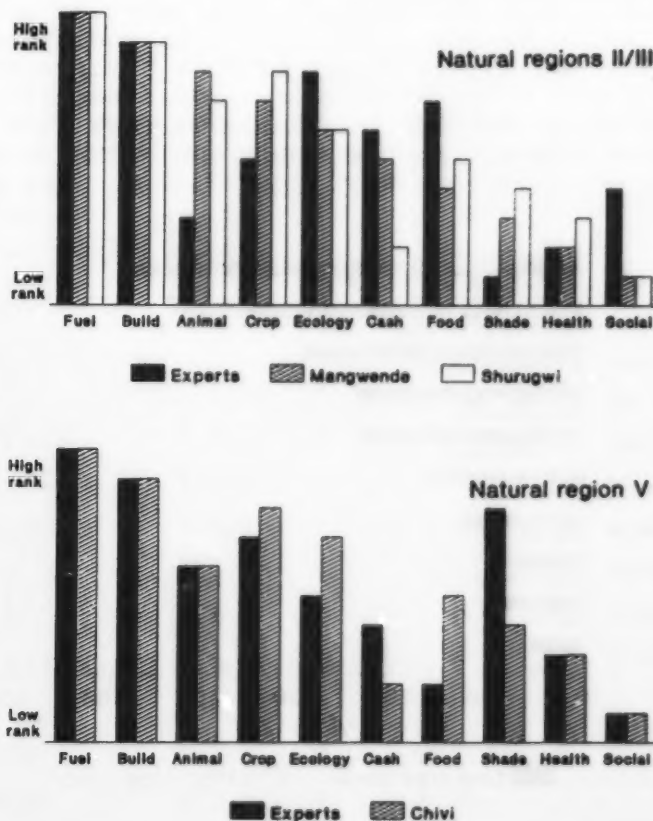


Figure 13. Ranks to tree commodity categories by experts and householders.

These results highlight the very different perceptions of value held by smallholder farmers, who capture most of the direct benefits and costs of tree resources and "experts" selected to represent informed members of society. In the development context the values of those who will directly bear the costs and derive the benefits of patterns of resource use are held to be paramount (Chambers, 1983).

CHAPTER FIVE: ECONOMICS OF INTERVENTIONS

Woodlots for Poles and Fuel

In response to the perceived problem of deforestation in Zimbabwe and the perceived shortage in fuelwood, the Rural Afforestation Project was implemented soon after independence (Forestry Commission, 1982). One central aspect of the project was the block planting of eucalypt. It is now becoming obvious that most rural populations consider the time and resources invested in block planting of fuelwood species uneconomical (Casey and Muir, 1988).

In the case of block planting by institutions or groups, the cost of producing fuelwood is very high. The high cost of producing wood in block plantations stems from high establishment costs, rather than from running costs. For instance, establishment costs at the urban plantation at Gweru (Casey, 1986) were over \$1600 ha⁻¹ (this includes only direct costs, not cost of land or technical staff salaries), whereas maintenance costs were about \$150 ha⁻¹ yr⁻¹ and harvesting and coppice reduction were nearly \$600 ha⁻¹. Establishment costs for the Forestry Commission of eight woodlots averaged over \$2000 ha⁻¹ (Casey, 1986). High establishment costs are characteristic in other countries as well. In Mali, establishment costs were US\$3000 ha⁻¹ (1986), including overheads and infrastructural support to the Forestry Service (Foley, 1988). The costs of establishment in later projects were US\$1400 ha⁻¹ (1986). Woodlots usually need to be fenced if they are to be productive, and fencing costs are high. Labour also forms a considerable component of the costs of a block planting, roughly 50% in the case of the Gweru plantation.

Coopers and Lybrand (1986) calculated the economic cost of fuelwood from eucalypt plantations for various regions in Zimbabwe. Their estimates indicate that wood from such plantations would cost between \$32 per tonne to \$40 per tonne. This is more than the present price of fuelwood in rural areas (Z\$28 per tonne, Questionnaire II, and this is the value for high-quality fuelwood rather than eucalypt, du Toit et al., 1984) thus giving no profit incentive to any organisation other than a charitable one! French (1986) comes to a similar conclusion for Malawi.

That the planting of trees for wood is not economical is related primarily to the presence of "free" trees in the communal grazing area. The only cost associated with this wood is that of harvesting: there are no establishment costs, no exclosures and no maintenance costs. Spears (1987) finds that the internal rate of return for fuelwood collection is 20 times higher than that achieved when growing fuelwood.

To achieve at least some level of cost recovery for a block plantation, a considerable percentage of wood from a block planting must be sold as poles rather than as fuelwood, and the wood has often to be sold at subsidised prices if anyone is to purchase it. Sales of wood from the Gweru plantation recovered only two-thirds of the costs incurred in the establishment, maintenance and harvesting of the block planting (Casey, 1986; Casey and Muir, 1988). Nearly 50% of the wood had to be sold as poles in order to achieve some level of cost recovery. Even the subsidised prices at this plantation are much higher than the prices acceptable in rural areas (e.g. Bradley and McNamara's, 1990, and our data suggest a 8 to 10 fold difference between prices in urban and rural areas). Only if prices increase dramatically in the next decades will block plantings have any role to play. Attwell et al. (1989), for the Harare urban area, show that fuelwood prices have not increased in real terms in the last decade. Even the establishment of peri-urban plantations is not considered financially worthwhile in Zimbabwe (Attwell et al., 1989).

Where there are good markets for tree products, the profitability of block plantings on small farms is beyond doubt if a farmer is able to make large investments (Foley, 1984). Foley calculates that the internal rate of return would be over 120% for timber plantations with high inputs. This is not the case if a farmer can only afford low inputs, planting trees on marginal land and using only family labour. Even if substantial profits could be realised after 5 to 10 years, tree growing will be ruled out if the farmer cannot support her/his family while the trees are growing (Foley, 1984). The number of trees planted will always be low, and will largely depend on the access to free or low-cost seedlings, the amount of labour available and the ease with which seedlings can be protected from livestock.

Fodder Banks

Although data are not available on the economics of block plantings for fodder in Zimbabwe, de Montgolfier-Kouevi and le Houerou (1980) have provided a detailed analysis for similar systems, chiefly based on *Acacia* plantations, in north Africa and the Sahel. They show that such plantations are not economical.

Establishment (excluding fencing) costs varied from US\$200-US\$500 ha⁻¹ at that time, with labour costs usually accounting for 80% of the total (purchase price of land and salaries for technical staff excluded). To this must be added fencing costs of around US\$450 ha⁻¹. Operating costs were found to be minimal (roughly US\$20 ha⁻¹ yr⁻¹). When exclosures were included in the design, the internal rate of return was only 5-12%, but without exclosures it rose to 12-21%. For most fodder banks it is not possible to do away with exclosures due to damage by livestock.

With a 15% internal rate of return, browse plantations are only economical if exclosures are unnecessary, if the plantations are high yielding and if co-products from the plantations are valuable (de Montgolfier-Kouevi and le Houerou, 1980). In Zimbabwe, however, dry season feed for livestock is such an important constraint that planting for fodder, using for example *Acacia angustissima*, is being tested as a possible intervention. Vegetable gardens, although small, provide an already protected site for these species.

Tree Nurseries and Subsidised Seedlings

It is common practice within farm forestry projects to provide subsidised tree seedlings. Such programmes could well lead to distortions in allocation to land, labour and capital, apart from being a drain on the resources of central government (Foley, 1984). Zimbabwe's Rural Afforestation Project set out to establish tree nurseries, and, by 1990, 75 nurseries were operative (World Bank, 1990). The nurseries grow mainly eucalypt seedlings, but in recent years the nurseries have also been used as distribution points for citrus trees. At some there have been attempts to produce small quantities of fruit trees like mulberry, mango and guava and fodder species such as *Leucaena leucocephala* and *Faidherbia albida*. Eucalypt seedlings sold by nurseries have been heavily subsidised. Direct costs per seedling in 1986 were roughly \$0.17, increasing to \$0.41 when nursery overheads were included. The seedlings were sold at between \$0.03 and \$0.05 each, or distributed free on National Tree Day (World Bank, 1990; see also Casey and Muir, 1988). The Forestry Commission is now handing these nurseries over to local councils and groups, and the subsidy is being phased out. This has already caused the price to increase up to about \$0.25 per seedling.

In some other countries, free or subsidised seedlings are followed by small cash incentives depending on the number of surviving plants. Such payments make heavy administrative demands, in terms of checking number of surviving plants and making payments (Foley, 1984). Such cash incentives were not a part of the Rural Afforestation Project in Zimbabwe.

Katerere (1987) records 57% of households as stating that their seedling sources were from home production, and another 27% as being free sources. Only 16% of households purchased their seedlings (and then presumably at subsidised prices). It is thus doubtful that nurseries in Communal Areas are going to have a major impact on tree-planting practices once subsidies are removed. However, if there is a shift in emphasis to more economically viable species, such as species used for fruit or fodder, nurseries may be viable in the future.



Large numbers of eucalypt seedlings are grown at Forestry Commission nurseries.

Alley-Cropping

For Zimbabwe there are no economic analyses for typical alley-cropping designs, and many of the published analyses (e.g. see Swinkels and Scherr, 1991) are not relevant to Zimbabwean conditions. In this section we draw on some of the literature relevant to semi-arid zones.

Spears (1987) shows how new agroforestry interventions increase overall rates of return to farmers. When only direct products are

considered, the rates of return are less than 8%, but when added to the positive impacts on crop yields the rates rise to above 16%. Hoekstra (1983) demonstrates that the net present value of hedgerow intercrops in a semi-arid system is superior to monoculture due to enhanced maize yield, while in contrast Lubega (1987) finds that hedgerows are not profitable. Favourable economic analyses for alley cropping are presented by Sturmheit (1989) for southern Zambia (maize and *Cassia siamea*). Shah (1988) also presents a favourable picture, with benefit-cost ratios increasing by 60% for *Leucaena*-based agroforestry as compared to monoculture. Mukhebi et al. (1985) finds that the choice between monoculture or intercropping depends upon soil fertility and rainfall conditions. The data presented by Osemeobo (1989) show that, for a small farmer, an agroforestry system is not any better than a pure crop system. Similarly, Ariza-Nino (1983), finds that the inclusion of a fodder bank of *Leucaena* intercropped during the first two years results in net present values that are similar to the monoculture system (labour costs were not included in the analysis).

CHAPTER SIX: CONCLUSIONS

General

The findings of this survey are tentative. For instance, in the context of contingent evaluation, Mitchell and Carson (1989) stress that for setting policy a sample size of at least 600 is required. Nevertheless, it is suggested that the results of this study provide clear foci for establishing research priorities and for the development of optimal tree resource policies.

The assessment of subsistence production in terms of economic value presents numerous methodological problems (Sinden and Worrell, 1979; Scoones, 1990). If a full economic analysis were to be done, it is clear that much more detailed site-specific data would be necessary on productivity, and on harvesting and production costs. Environmental costs of different activities would have to be valued.

The values we derive are from the perspective of the household. A much more important valuation remains to be done. What is the value of woodland from the perspective of society? Or, what are the costs of deforestation? Methodologies to assess the "ecological value" of woodlands need to be developed. The deterioration in soil organic matter and structure accompanying deforestation has cost effects either in terms of decreased crop yields or the need to increase inputs to maintain yields. Further costs arise due to increased soil erosion associated either directly or indirectly with deforestation and subsequent flood damage or silting of water supplies.

Another way of valuing woodland is to examine the costs of planting trees. The establishment cost is at least \$2000 ha⁻¹ and this leads to a woody plant cover of trees with limited use, not a diverse woody plant cover with fruits, browse and high quality wood. What are the costs associated with the planting of a diverse tree resource? Unfortunately, there are no economic analyses for agroforestry initiatives such as intercropping and alley cropping in Zimbabwe.

The categories used in the contingent analysis are obviously too broad to identify meaningful research projects. The results do

however, clearly indicate the categories of tree commodity that need to be focused on. Research should then be directed to investigating these categories in more detail and in so doing highlight technological and institutional needs.

The values placed on tree resources by smallholder farmers are likely to differ markedly from those held by researchers and administrators. This could result in setting research and policy agendas that are inappropriate to the needs of smallholder farmers and hence society at large. It is of great importance therefore, that the values of smallholder farmers are given due consideration in planning resource use policies and agroforestry interventions in the smallholder farming sector.

Overall Value

Goods and services derived from trees have been shown to be very valuable from the perspective of the household. Trees play a multi-purpose role in this sector. They provide: almost all of the



Pestle and mortar, important wooden utensils in any household.

household energy; many of the timber needs for building, fencing and manufacture of household utensils and agricultural equipment; sources of wild foods, most importantly fruits; inputs to maintain soil fertility in cultivated fields; much of the livestock feed in the late dry season and a host of other more intangible benefits such as spiritual value, medicines and shade.

The value of trees can be gauged by the practices of farmers: wild fruit trees are conserved in cultivated fields even though government agricultural extension services formerly discouraged this practice; farmers have resisted bush-clearing directives because of the value of browse; and, households spend considerable time collecting woodland litter for application to cultivated fields.

We estimate that the woodland provides products worth about Z\$1000 yr⁻¹ to a household. The value of the woodland in terms of such products is about Z\$200 ha⁻¹ yr⁻¹. However, we stress that the data for such estimates is limited. The contingent valuation technique gives much lower values to tree resources. Although a considerable proportion of the variability is due to methodology, and the high valuation given to products from trees is an overestimate due to the reasons discussed, it is likely that small-scale farmers underestimate value in the contingent valuation technique because trees are a common property, with more or less open access.

Fuelwood

The concerns from experts in social forestry have until recently focussed on fuel and the planting of trees for fuelwood (French, 1986; Chidumayo, 1988; DeWees, 1989). We believe that sufficient data have been presented above and in the international literature to suggest that an emphasis on fuelwood is totally misdirected. Simply from a financial perspective, there appear to be inadequate rural fuelwood and pole markets to support anything like a national programme of woodlot development (Bradley and McNamara, 1990). If there are to be woodlots for wood production, small-scale farmers are more interested in planting for timber than for fuel and, in any event, a certain amount of fuelwood will be produced if timber trees are planted. On a per tonne basis, timber sells at twice the price of fuelwood in rural areas.

Fruit Trees

The importance of fruit trees in the household economy is illustrated by our data. Farmers may be considered to undertake informal cost-benefit analysis of their various farming activities. That they are interested in planting fruit trees but not eucalypt woodlots is, of course, indicative of the marginal productivities of fruit trees and eucalypts. These marginal productivities determine farmer preferences and demonstrate value. In any tree-planting programme, fruit trees should be given priority.

Indigenous Woodlands

Our results suggest that more emphasis should be placed on the resources of indigenous woodlands than on planted woodlots. Greater research effort must be directed towards indigenous woodlands so that they can be managed to ensure high productivity and sustainability. A large number of questions need to be answered. For example, how can productivity be increased by coppicing strategies? Does water harvesting increase productivity?

Tree-Planting

The importance of trees in the small-scale sector does not necessarily mean that forestry interventions are economical or acceptable to farmers. Block planting initiatives and seedling provision in Zimbabwe are heavily subsidised by government. It is doubtful that nurseries in Communal Areas are going to have a major impact on tree-planting practices once subsidies are removed. As Foley (1984) argues, if the use of subsidies is necessary to persuade people to do something, it is prudent to question whether it is truly in their interest. In the case of tree-planting by the really poor, there may be a need for a provision of incentives because of the long time interval before any benefits are realised.

The Rural Afforestation Programme in Zimbabwe has been on-going for about a decade. The results of the tree-planting initiatives in Zimbabwe need to be assessed, and the emphasis on seedling provision needs to be carefully evaluated. Has there been a tremendous upsurge of interest in tree-planting as a result of the nurseries, woodlots and agricultural extension? Is there any justification for maintaining subsidies on seedlings? Does the cost of deforestation to society justify the subsidy level? Should planting continue to focus on eucalypt? There is clearly a need to repeat aspects of the baseline survey undertaken in 1982 (du Toit et al., 1984).

That block planting and seedling provision are uneconomical at present simply means that the "free resources" of the woodland are present in relatively large quantities. Only with much greater deforestation will the value of woodland goods rise to a point where tree-planting becomes an attractive option. At this point the cost to society in terms of degradation may be large.

The prohibitively high costs of tree-planting initiatives are primarily due to labour and exclosures. Labour costs are difficult to circumvent as labour is chiefly a constraint in the wet season, when tree-planting should be taking place. It appears that tree-planting at present will be successful only where labour is not valued highly, for example in schools. Exclosures are needed to protect seedlings from livestock. Tree-planting initiatives should be concentrated in the homestead area where protection is more easily organised, and in vegetable gardens, where brush fencing is already common. We may therefore ask why agroforestry initiatives are largely directed towards staple crops, which are planted in areas where there is usually no protection from livestock during the dry season? Should not more attention be paid to tree-vegetable interactions? Other prohibitive costs for tree-planting come from termiticides and fertilisers, whose use will not be possible by small-scale farmers.

Stumpage Fees

Policy options attempting to commercialise trade in wood products by the use of "stumpage fees", as argued for in World Bank working works (Openshaw and Feinstein, 1988; Teplitz-Sembitzky and Schramm, 1989), represents one of the most important ways of raising the value of indigenous woodland to cover the replacement cost of wood. Stumpage fees would promote frugality and reduce deforestation rates. The fees collected could be used in community development initiatives. However, small-scale farmers can ill-afford the inputs necessary for agriculture, let alone a stumpage fee when extracting wood. Furthermore, a programme involving stumpage fees would increase the administrative demands on local institutions.

Tenure

Patterns of ownership of tree resources probably play a role in determining attitudes and practices regarding trees and woodlands. There are at present limited data on this subject in Zimbabwe. Due in large to the present property rights that exist, tree resources are likely to be significantly undervalued and therefore consumed

inefficiently. Whilst smallholder values do appear to reflect relative scarcity, the absence of market-based price cues and non-attenuated property rights could result in inefficient resource utilisation. Research is urgently required to identify institutions which will stimulate the efficient management and utilisation of tree resources in the smallholder sector.

Integrated Approach

To improve the management of these resources and ensure the sustainability of production from them an integrated approach to setting research priorities and identifying policy objectives is recommended. This should include; a) clear identification of the needs of smallholder farmers in a given ecological, socio-economic and political environment; b) identification of the resource base and the values of farmers for those resources; c) establishing the production and consumption functions of households and the resources; d) identification of markets and marketing opportunities for trade in tradeable tree resources; e) identification of institutions to govern the use of non-exclusive, non-rival and congestible tree resources.



One of the less orthodox uses of trees.

REFERENCES

- Abel, N.O.J., Drinkwater, M.J., Ingram, J., Okafor, J. and Prinsley, R. (1989). *Agroforestry for Shurugwi, Zimbabwe: report of an appraisal exercise for agroforestry research and extension*. Technical Paper 277. London: Commonwealth Science Council, 229 pp.
- Agritex (1982). *Agritex Agroforestry Policy Document*. Harare: Agritex.
- Allen, E.N. and Allen, O.N. (1961). The scope of nodulation in the Leguminosae. *Recent Advances in Botany*. 1: 583-588.
- Ariza-Nino, E.J. (1983). *Livestock and agroforestry in peasant farms of Africa: illustrative modelling and methodology*. Unpublished draft. Nairobi: International Council for Research in Agroforestry and Ann Harbor, Michigan: Centre for Research on Economic Development, University of Michigan.
- Arnold, M. (1991). *Socioeconomic aspects of smallholder tree growing. Zimbabwe: country report*. Unpublished manuscript of Oxford Forestry Institute.
- Attwell, C.A.M., Campbell, B.M., du Toit, R.F. and Lynam, T.J.P. (1989). *Patterns of fuelwood utilisation in Harare, Zimbabwe*. Harare: World Bank and Forestry Commission.
- Aucamp, A.J., Danckwerts, J.E., Teague, W.R. and Venter, J.J. (1983). The role of *Acacia karroo* in the False Thornveld of the Eastern Cape. *Proceedings of the Grassland Society of Southern Africa*. 18: 151-154.
- Balderrama, S., Fenta, T., Hussein, A., Jackson, C., Midre, M., Scott, C., Vasquez, C. and de Vos, J. (1988). *Farming system dynamics and risk in a low potential area: Chivi South, Masvingo Province, Zimbabwe*. ICRA Bulletin 27. Wageningen, the Netherlands: International Course for Development Oriented Research in Agriculture.
- Barnes, D.L. (1976). A review of plant-based methods of estimating food consumption, percentage utilisation, species preferences and

feeding patterns of grazing and browsing animals. *Proceedings of the Grassland Society of Southern Africa*. 11: 65-71.

Barnes, D.L. (1979). Cattle ranching in the semi-arid savannas of East and Central Africa. In B.H. Walker, ed. *Management of semi-arid ecosystems*. Amsterdam: Elsevier, pp. 9-54.

Bate, G.C. (1979). Nitrogen in Southern African savannas. *Dynamic Changes in Savanna Ecosystems*. Pretoria: CSIR.

Belsky, A.J., Amundson, R.G., Duxbury, J.M., Riha, A.R. and Mwonga, S.M. (1989). The effect of trees on their physical, chemical and biological environment in the semi-arid savanna in Kenya. *Journal of Applied Ecology*. 26: 1005-1024.

Bishop, R. C. 1982. Option value: an exposition and extension. *Land Economics*. 58: 1-15.

Bishop, R.C. and Heberlein, T.A. (1979). Measuring values of extramarket goods: are indirect measures biased? *American Journal of Agricultural Economics*. 61: 926-930.

Bishop, R.C., Heberlein, T.A. and Kelly, M.A. (1983). Contingent valuation of environmental assets: Comparisons with a simulated market. *Natural Resources Journal*. 23: 619-633.

Blair Research Laboratory. 1989. *The Blair Latrine Builders Manual*. Ministry of Health, Harare, Zimbabwe.

Bosch, O.J.H. and van Wyk, J.J.P. (1970). The influence of bushveld trees on the productivity of *Panicum maximum*. *Proceedings of the Grassland Society of South Africa*. 5: 69-74.

Bradley, P.N. and McNamara, K. (1990). *The role of trees and woodlands in Zimbabwe's Communal Areas*. Background paper prepared for World Bank Agricultural Sector Memorandum. Stockholm: Stockholm Environment Institute, 34 pp.

Bratton, M. (1987). Drought, food and the social organisation of small farmers in Zimbabwe. In M.H. Glentz, ed. *Drought and hunger in Africa: denying famine a future*.

Brookshire, D.S. and Coursey, D.L. (1987). Measuring the value of a public good: An empirical comparison of elicitation procedures. *The American Economic Review*. 77: 554-566.

Brookshire, D.S., Eubanks, L.S. and Randall, A. (1983). Estimating option prices and existence values for wildlife resources. *Land Economics*. 30: 1-15.

- Brookshire, D.S., Ives, B.C. and Schulze, W.D. (1976). The valuation of aesthetic preferences. *Journal of Environmental Economics and Management*. 3: 325-346.
- Brookshire, D.S., Randall, A. and Stoll, J.R. (1980). Valuing increments and decrements in natural resource service flows. *American Journal of Agricultural Economics*. 62: 478-488.
- Burford, N.F. (1989). *Firewood and fence pole acquisition consumption patterns and tree planting practices in a Zimbabwean village*. B.Sc. Hons. thesis, University of Wales.
- Campbell, B.M. (1987). The use of wild fruits in Zimbabwe. *Economic Botany*. 41: 375-385.
- Campbell, B.M., Clarke, J.M. and Gumbo, D.J. (1991). Traditional agroforestry practices in Zimbabwe. *Agroforestry Systems* (in press).
- Campbell, B.M. and du Toit, R.F. (1988). Relationships between wood resources and use of species in the communal lands of Zimbabwe. *Monographs in Systematic Botany of the Missouri Botanical Garden*. 25: 331-341.
- Campbell, B.M. and du Toit, R.F. (in press). The plant communities of the Save-Mucheki confluence, with particular attention to the influence of peasant agricultural systems. *Kirkia* (in press).
- Campbell, B.M., Swift, M.J., Hatton, J.C. and Frost, P.G.H. (1988). Small-scale vegetation pattern and nutrient cycling in miombo woodland. In J.T.A. Verhoeven, G.W. Heil and M.J.A. Werger, eds. *Vegetation structure in relation to carbon and nutrient economy*. The Hague: SPB Academic Publishing, pp. 69-85.
- Casey, J. (1986). *Economic analysis of urban fuelwood plantations based on Gweru plantation data*. Harare: Forestry Commission, Monitoring and Evaluation Unit.
- Casey, J. and Muir, K. (1988). *Institutional responsibility for social forestry in Zimbabwe*. Working paper, Department of Agricultural Economics and Extension, University of Zimbabwe. 12 pp.
- Chambers, R.J.H. (1983). *Rural development: Putting the last first*. Harlow, U.K.: Longman Scientific & Technical.
- Chambers, R.J.H. (1988). *Trees as savings and security for the rural poor*. Gatekeeper Series Number SA3. London: International Institute for Environment and Development. 10 pp.

Charreau, C. and Vidal, P. (1965). Influence de l'*Acacia albida* sur le sol, nutrition, minerales et rendements des mils *Pennisetum* au Senegal. *Agronomie Tropicale*.

Chidumayo, E.N. (1988). Integration and role of planted trees in a bush fallow cultivation system in central Zambia. *Agroforestry Systems*. 7: 63-76.

CIMMYT. (1982). *Demonstration of an interdisciplinary approach to planning adaptive research programmes*. Report No. 5 November 1982 - Part of Chivi District Southern Zimbabwe. Nairobi: CIMMYT.

Clarke, J.M. (1983). *A socio-ecological study of a rural community in the northern Sebungwe*. M.Sc. thesis, University of Zimbabwe.

Coopers and Lybrand Associates (1986). *Energy pricing study*. Appendix 6: Fuelwood. Ministry of Energy, Water Resources and Development and the World Bank.

Cummings, R.G., Brookshire, D.S. and Schulze, W.D. (1986). *Valuing environmental goods: an assessment of the contingent valuation method*. Ottawa: Rowman and Allanheld.

Davis, R.K. (1963). Recreation planning as an economic problem. *Natural Resources Journal*. 3: 239-249.

de Montgolfier-Kouevi, C. and le Houerou, H.N. (1980). Study on the economic viability of browse plantations in Africa. In H.N. le Houerou, ed. *Browse in Africa: the current state of knowledge*. Addis Ababa: International Livestock Centre for Africa, pp. 449-464.

DeWees, P.A. (1989). The woodfuel crisis reconsidered: observations on the dynamics of abundance and scarcity. *World Development*. 17: 1159-1172.

Dube, J.S. The nutritive value of browse species preferred by goats in Thornveld. *Zimbabwe Agricultural Journal*. 85.

du Preez, D.R., Gunton, C. and Bate, G.C. (1983). The distribution of macronutrients in a broad leaf woody savanna. *South African Journal of Botany*. 2: 236-242.

du Toit, R.F., Campbell, B.M., Haney, R.A. and Dore, D. (1984). *Wood usage and tree planting in Zimbabwe's Communal Lands*. Report produced for the Forestry Commission of Zimbabwe and the World Bank. 187 pp.

du Toit, R.F. and Campbell, B.M. (1988). Environmental degradation. In B.M. Campbell, R.F. du Toit and C.A.M. Attwell, eds. *The Save study: relationships between the environment and basic needs*

satisfaction in the Save catchment, Zimbabwe. Supplement to *Zambezia*, Journal of the University of Zimbabwe. Harare: University of Zimbabwe, pp. 34-43.

Dye, P.J. and Spear, P.T. (1982). The effects of bush clearing and rainfall variability on grass yield and composition in south-west Zimbabwe. *Zimbabwe Journal of Agricultural Research*. 20: 103-118.

Dye, P.J. and Walker, B.H. (1980). Vegetation-environment relations in sodic soils of Zimbabwe. *Journal of Ecology*. 68: 589-606.

Elwell, H.A. (1981). A soil loss estimation technique for southern Africa. In *Soil conservation problems and prospects*. Wiley Interscience, pp. 281-292.

Elwell, H.A. (1986). Determination of erodibility of a subtropical clay soil: a laboratory simulation experiment. *Journal of Soil Science*. 37: 345-350.

Ernst, W.H.O. (1975). Variation in the mineral contents of leaves in miombo woodlands in South Central Africa. *Journal of Ecology*. 63: 801-808.

Ernst, W.H.O. and Tolsma, D.J. (1989). Mineral nutrients in some Botswana savanna types. In J. Proctor, ed. *Mineral nutrients in tropical forest and savanna ecosystems*. Oxford: Blackwell Scientific Publications.

Felker, P. (1978). State of the art: *Acacia albida* as a complementary permanent intercrop with annual crops. Report to USAID. Riverside, California: University of California, 133 pp.

Foley, G. (1984). *The evolution of woodfuel demand in Mali: an outline case study*. Earthscan Energy Information Programme. 80 pp.

Foley, G. (1988). Discussion paper on demand management. Panos Institute, London. Paper prepared for World Bank Eastern and Southern Africa Regional Seminar on Household Energy Planning. 1-5 February 1988, Harare.

Forestry Commission (1982). *The Rural Afforestation Project*. Harare: Forestry Commission.

French, D. (1986). Confronting an unsolvable problem: deforestation in Malawi. *World Development*. 14: 531-540.

Frost, P.G.H. (1985). Organic matter and nutrient dynamics in a broadleaved African savanna. In J.C. Tothill and J.J. Mott, eds. *Ecology and management of the world's savannas*. Canberra: Australian Academy of Science, pp. 200-206.

- FSRU. (1985). *Farming Systems Research Unit Annual Report. Annual Report 1983-84*. Department of Research and Specialist Services, Harare, Zimbabwe.
- Gambiza, J. (1987). *Some effects of different stocking intensities on the physical and chemical properties of the soil in a marginal rainfall area of southern Zimbabwe*. M.Sc. thesis, Department of Biological Sciences, University of Zimbabwe.
- Gammon, D.M. (1983). Effects of bush clearing, stocking rates and grazing systems on vegetation and cattle gains in the south western lowveld of Zimbabwe. *Zimbabwe Agricultural Journal*. 80: 219-228.
- Gelfand, M., Mavi, S., Drummond, R.B. and Ndemera, E.B. (1985). *The traditional medical practitioner in Zimbabwe*. Gweru, Zimbabwe: Mambo Press.
- Georgiadis, N.J. (1989). Microhabitat variation in an African savanna: effects of woody cover and herbivores in Kenya. *Journal of Tropical Ecology*. 5: 93-108.
- Glover, P.E., Glover, J. and Gwynne, M.D. (1962). Light rainfall and plant survival in East Africa. *Journal of Ecology*. 50: 199-204.
- Grant, P.M. (1981). The fertilization of sandy soils in peasant agriculture. *Zimbabwe Agricultural Journal*. 78: 169-175.
- Griffioen, C. and O'Connor, T.G. (1990). The influence of trees and termite mounds on the soils herbaceous composition of a savanna grassland. *South African Journal of Ecology*. 1: 18-26.
- Grossman, D., Grunow, J.O. and Theron, G.K. (1980). Biomass cycles, accumulation rates and nutrient characteristics of grass layer plants in canopied and uncanopied subhabitats in *Burkea* savanna. *Proceedings of the Grassland Society of South Africa*. 15: 157-161.
- Grundy, I. (1990). *The potential for management of the indigenous woodland in Communal Farming Areas of Zimbabwe, with reference to the regeneration of Brachystegia spiciformis and Julbernadia globiflora*. M.Sc. thesis, University of Zimbabwe.
- Grundy, I.M., Campbell, B.M., Balebereho, S., Cunliffe, R., Tafangenyasha, C., Fergusson, R. and Parry, D. (in press). Availability and use of trees in Mutanda Resettlement Area, Zimbabwe. *Forest Ecology and Management*.
- Gumbo, D.J., Mukamuri, B.B., Muzondo, M.I. and Scoones, I.C. (1990). Indigenous and exotic fruit trees: why do people want to grow them? In R.T. Prinsley, ed. *Agroforestry for sustainable production*:

- economic implications*. London: Commonwealth Science Council, pp. 185-214.
- Hoehn, J.P. and Randall, A.. (1987). A satisfactory benefit cost indicator from contingent valuation. *Journal of Environmental Economics and Management*. 14: 226-247.
- Hoekstra, D.A. (1983). An economic analysis of a simulated alley-cropping system for semi-arid conditions, using micro-computers. *Agroforestry Systems*. 1: 335-345.
- Hogberg, P. (1986). Nitrogen-fixation and nutrient relations in savanna woodland trees (Tanzania). *Journal of Applied Ecology*. 23: 675-688.
- Hosier, R.H. (1986). *Zimbabwe: energy planning for national development*. Energy, environment and development in Africa 9. Stockholm: Beijer Institute, 206 pp.
- Houghton, R.A. (1990). The future role of tropical forests in affecting the carbon dioxide concentration of the atmosphere. *Ambio*. 19: 204-209.
- Imbach, A.C., Fassbender, H.W., Borel, R., Beer, J. and Bonneman, A. (1989). Modelling agroforestry systems of cacao (*Theobroma cacao*) with laurel (*Cordia alliodora*) and cacao with poro (*Erythrina poeppigiana*) in Costa Rica. IV. Water balances, nutrient inputs and leaching. *Agroforestry Systems*. 8: 267-287.
- Ingram, J. (1989). *Tree-crop interfaces*. Unpublished report to Commonwealth Science Council.
- Ingram, J. (1990). The role of trees in maintaining and improving soil productivity a review of the literature. In R.T. Prinsley, ed. *Agroforestry for sustainable production: economic implications*. London: Commonwealth Science Council, pp. 243-303.
- Kang, B.T., Grimme, H. and Lawson, T.L. (1985). Alley cropping sequentially cropped maize and cowpea with *Leucaena* on a sandy soil in southern Nigeria. *Plant Soil*. 85: 267-277.
- Katerere, Y. (1987). Tree planting activities in rural Zimbabwe. In ETC Foundation *SADCC Energy Development: Fuelwood Study*. Leusden, the Netherlands, annex I, 11 pp.
- Kellman, M. (1979). Soil enrichment by neotropical savanna trees. *Journal of Ecology*. 67: 565-577.

- Kelly, R.D. (1973). *A comparative study of primary productivity under different kinds of land use in Southern Rhodesia*. Ph.D. thesis, University of London.
- Kennan, T.C.D. (1969). The significance of bush in grazing land in Rhodesia. *The Rhodesia Science News*. 11: 331-336.
- King, J.A. and Campbell, B.M. (in preparation). Soil organic matter under miombo woodlands, plantations, grassland and maize crops.
- Knetsch, J.L. and Sinden, J.A. (1984). Willingness to pay and compensation demanded: experimental evidence of an unexpected disparity in measures of value. *Quarterly Journal of Economics*. 94: 507-521.
- Knoop, W.T. and Walker, B.H. (1985). Interactions of woody and herbaceous vegetation in a southern African savanna. *Journal of Ecology*. 73: 235-253.
- Lawton, R.M. (1982). Natural resources of miombo woodland and recent changes in agricultural and land-use practices. *Forest Ecology and Management*. 4: 287-297.
- le Houerou, H.N. (1980). Chemical composition and nutritive value of browse in West Africa. In H.N. le Houerou, ed. *Browse in Africa: the current state of knowledge*. Addis Ababa: International Livestock Centre for Africa, pp. 261-290.
- Lubega, A.M. (1987). *Economic feasibility of rural projects in semi-arid areas of developing countries: a case study of agroforestry in Kenya*. Ph.D. thesis, Department of Environmental Studies, State University of New York.
- Materechera, S.A. (1988). The utilisation of indigenous tree species in some smallholder agroforestry systems in Malawi: a review. Paper presented at international workshop on *Utilisation and exploitation of indigenous and often neglected plants and fruits of eastern and southern Africa*. 21-27 August 1988, Chancellor College, University of Malawi, Zomba.
- Mazambani, D. (1984). *Commodification of woodfuel in Zimbabwe's urban areas: a case study of Harare and Chitungwiza, 1980-1984*. ZEAP Working Paper 9. Stockholm: Beijer Institute, 12 pp.
- Mendelsohn, R. and Brown, G.M. (1983). Revealed preference approach to valuing outdoor recreation. *Natural Resources Journal*. 607-618.
- Milton, S.J. (1983). *Acacia tortilis* subsp. *heteracantha* productivity in the Tugela Dry Valley Bushveld: preliminary results. *Bothalia*. 14: 767-772.

Milton, S.J. and Bond, C. (1986). Thorn trees and the quality of life in Msinga. *Social Dynamics*. 12: 64-76.

Ministry of Energy and Water Resources Development (MEWRD). (1985). Rural willingness to pay for water supplies. Annex 1 to Water Tariff Study. *National Master Plan for Rural Water Supply and Sanitation*. Harare: NORAD / INTERCONSULT.

Ministry of Environment and Tourism. (1990). *National Forest Policy*. Cabinet memorandum by the Honourable H.M. Murerwa, Minister of Environment and Tourism.

Mitchell, R.C. and Carson, R.T. (1989). *Using surveys to value public goods: the contingent valuation method*. Washington, D.C.: Resources for the Future.

Mudimu, G., Chopak, C., Chigume, S., Govereh, J. and Bernsten, G. (1989). Household income, food production and marketing in low-rainfall areas of Zimbabwe: status, constraints and opportunities. In M.Rukuni, G. Mudimu and T.S. Jayne, eds. *Food Security Policies in the SADCC Region*. Proceedings of the Fifth Annual Conference on Food Security Research in Southern Africa. Harare, Zimbabwe, 16-18 October, 1989.

Mukhebi, A.W., Onim, J.F.M. and Oyugi, L. (1985). Economics of intercropping maize with forage crops in small-scale farming systems in western Kenya. *Proceedings of second PANESA workshop on livestock feed resources for small-scale livestock producers*. Nairobi: International Council for Research in Agroforestry, pp. 220-230.

Olsvig-Whittaker, L. and Morris, J.W. (1982). A comparison of certain Nysvley soils using a bioassay technique. *South African Journal of Botany*. 1: 91-96.

Openshaw, K. and Feinstein, C. (1988). *Fuelwood stumpage: considerations for developing country energy planning*. Industry and Energy Department Working Paper. Energy Series Paper 16. Washington, D.C.: World Bank, 51 pp.

Osemeobo, G.J. (1989). An impact and performance evaluation of smallholder participation in tree planting, Nigeria. *Agricultural Systems*. 29: 117-135.

Pereira, H.C., McCulloch, J.G., Dagg, M. and Kerfoot, O. (1962). Hydrological effects of changes in land use of some East African catchment areas. *East African Agriculture and Forestry Journal*. 27 (special issue).

Plowes, D.C.H. (1956). Bush or grass, which do we want? *Rhodesia Agricultural Journal*. 53: 589-595.

- Purseglove, J.W. (1968). *Tropical crops: dicotyledons*. Burnt Mill, Essex, U.K.: Longman, 719 pp.
- Randall, A. (1983). The problem of market failure. *Natural Resources Journal*. 23: 131-148.
- Randall, A., Hoehn J.P. and Brookshire, D.S. (1983). Contingent valuation surveys for evaluating environmental assets. *Natural Resources Journal*. 23: 635-648.
- Reh, I., van Oosterhout, S.A.M., Campbell, B.M. and du Toit, R.F. (1988). Resource use and agricultural production. In B.M. Campbell, R.F. du Toit and C.A.M. Attwell, eds. *The Save study: relationships between the environment and basic needs satisfaction in the Save catchment, Zimbabwe*. Supplement to *Zambezia*, Journal of the University of Zimbabwe. Harare: University of Zimbabwe, pp. 15-33.
- Reiling, S.D., Boyle, K.J., Philips M.L. and Anderson, M.W. (1990). Temporal reliability of contingent values. *Land Economics*. 66: 128-134.
- Rutherford, M.C. (1979). Plant-based techniques for determining available browse and browse utilisation: a review. *Botanical Review*. 45: 203-228.
- Sayce, K., ed. (1987). *Encyclopedia Zimbabwe*. Harare: Quest, 431 pp.
- Schultze, W.D., d'Arge, R.C. and Brookshire, D.S. (1981). Valuing environmental commodities: some recent experiments. *Land Economics*. 57: 151-172.
- Scoones, I.C. (1990). *Livestock populations and the household economy: a case study from southern Zimbabwe*. Ph.D. thesis, University of London.
- Shah, P. (1988). Potential of agroforestry as land use technology for rural poor. *Advances in Forestry Research*. 1: 28-100.
- Shumba, E. (1984). Animals and the cropping system in the communal areas of Zimbabwe. *Zimbabwe Science News*. 18: 99-102.
- Sibanda, R. The browsing and general behaviour of indigenous goats in thornveld. *Zimbabwe Agricultural Journal*. 84.
- Sinden, J.A. and Worrell, A.C. (1979). *Unpriced values: decisions without market prices*. New York: Wiley-Interscience, 511 pp.
- Spears, J. (1986). *Measuring the impact of forests and farm trees on water availability, soil fertility, crop and livestock yields with special reference to Africa*. AGRPT, 37 pp.

- Spears, J. (1987). Agroforestry: a development-bank perspective. In H. Steppeler, ed. *Agroforestry: a decade of development*. Nairobi: International Council for Research in Agroforestry, pp. 53-66.
- Stocking, M.A., Bojo, J. and Abel, N. (1989). *Financial and economic analysis of agroforestry: key issues*. Paper prepared for the workshop on agroforestry for sustainable development- economic implications. 17-21 April 1989, Swaziland.
- Stuart-Hill, G.C. (1987). Refinement of a model describing forage production, animal production and profitability as a function of bush density in the False Thornveld of the Eastern Cape. *Journal of Grassland Society of Southern Africa*. 4: 18-24.
- Stuart-Hill, G.C., Tainton, N.N. and Banard, H.J. (1987). The influence of an *Acacia karroo* tree on grass production in its vicinity. *Journal of Grassland Society of Southern Africa*. 4: 83-88.
- Sturmheit, P. (1989). *An ex-ante economic analysis of simulated maize monocropping and Cassia siamea/maize alley cropping systems in the maize/cattle farming areas of southern Zambia*. M.Sc. thesis, University College of North Wales.
- Swift, M.J., Frost, P.G.H., Campbell, B.M., Hatton, J.C. and Wilson, K.B. (1989). Nitrogen cycling in farming systems derived from savanna: perspectives and challenges. In M. Clarholm and L. Bergstrom, eds. *Ecology of arable land*.
- Swinkels, R.A. and Scherr, S.J. (1991). *Economic analysis of agroforestry technologies: an annotated bibliography*. Nairobi: International Council for Research in Agroforestry, 215 pp.
- Teplitz-Sembitzky, W. and Schramm, G. (1989). *Woodfuel supply and environmental management*. Industry and Energy Department Working Paper. Energy Series Paper 19. Washington, D.C.: World Bank, 30 pp.
- Vincent, V. and Thomas, R.G. (1960). *An agro-ecological survey of Southern Rhodesia. Part 1: Agro-ecological Survey*. Salisbury, Rhodesia: Government Printer.
- Walker, B.H. (1980). A review of browse and its role in livestock production in southern Africa. In H.N. le Houerou, ed. *Browse in Africa: the current state of knowledge*. Addis Ababa: International Livestock Centre for Africa, pp. 7-24.
- Wehmeyer, A.S. (1966). The nutrient composition of some edible wild fruits found in the Transvaal. *South African Medical Journal*. 40: 1102-1104.

Weinmann, H. (1948). Seasonal growth and changes in chemical composition of the herbage on Marandellas sandveld. *Rhodesia Agricultural Journal*. 45: 119-131.

West, O. (1950). Indigenous tree crops for southern Rhodesia. *Rhodesia Agricultural Journal*. 47: 204-217.

Whitlow, J.R. (1979). The household use of woodland resources in Rural areas. Harare: NR Board.

Whitlow, J.R. (1980). Deforestation in Zimbabwe. Supplement to *Zambezia*. Harare: University of Zimbabwe.

Whitsun Foundation (1981). *Rural Afforestation Study*. Harare: Whitsun Foundation.

Whittington, D., Briscoe, J., Mu, X. and Barron, W. (1986). Estimating the willingness to pay for water services in developing countries: a case study of the use of contingent valuation surveys in Southern Haiti. Paper delivered at the Regional Science Association Annual Meeting, Columbus, Ohio, 1986.

Wilson, A.D. (1969). A review of browse in the nutrition of grazing animals. *Journal of Range Management*. 22: 23-28.

Wilson, K.B. (1989a). Trees in fields in southern Zimbabwe. *Journal of Southern African Studies*. 15: 369-383.

Wilson, K.B. (1989b). The ecology of wild resource use for food by rural southern Africans: why it remains so important. Paper presented at conference on *The destruction of the environment and the future of life in the Middle East and Africa*. 14-17 July 1989.

Wilson, K.B. (1990). *Ecological dynamics and human welfare: a case study of population, health and nutrition in Southern Zimbabwe*. Ph.D. thesis, University of London.

World Bank (1982). *Zimbabwe: issues and options in the energy sector*. ESMAP.

World Bank (1990). *Project Completion Report Zimbabwe - Rural Afforestation Project*. Cr 1368-ZIM. Agricultural Operations Division, Southern African Department, Africa Region.

Young, A. (1987). *The potential of agroforestry for soil conservation. II. Maintenance of fertility*. International Council for Research in Agroforestry Working Paper 43. Nairobi: ICRAF.

Young, A. (1989). *Agroforestry for soil conservation*. CAB International. Exeter: BPCC Wheatons Ltd.

Young, A. and Muraya, P. (1990). *SCUAF: soil changes under agroforestry: a predictive model (version 2): computer program with user's handbook*. Nairobi: International Council for Research in Agroforestry, 124 pp.

APPENDIX 1: VALIDITY CHECKS FOR CONTINGENT ANALYSIS

Methods

Following Mitchell and Carson (1989), the overall validity of the elicited responses was considered to be a function of content, criterion and construct validity. The content of the questionnaire used in the study was validated by a) circulating it among professionals and colleagues for comment and discussion and b) holding a half-day workshop to review and finalise the questionnaire content.

The criteria used to establish the values of smallholder farmers were assumed to be valid if:

1. The expected value of the borehole, derived from the stated WTP values of respondents without access to a borehole, accurately reflects the expected costs of installing a borehole.
2. Category scores for the Blair toilet, standardised against borehole scores, and multiplied by the value of the borehole derived from respondents' WTP values, provide accurate indications of the expected costs of installing a Blair toilet.

To validate the first assumption, actual costs of building and installing hand boreholes were obtained from Blair Laboratories, Harare. These costs were compared to the values derived in the contingent value questions.

To validate the second assumption the WTP data for the borehole were used to calculate an expected value for a Blair toilet. These calculated values were compared to the actual costs of building a Blair toilet that were obtained from Blair Laboratories, Harare.

Construct validity (the degree to which the measure relates to other measures as predicted by theory) was established by a) developing hypotheses as to expected theoretical relationships in the data (Mitchell and Carson, 1989; Sinden and Worrell, 1979) and b) using two different methods to measure respondents' perceptions of the value of a borehole. The construct under question will be considered valid if the expected theoretical relationships are substantiated by the data and if the different measures converge to

the same result (Mitchell and Carson, 1989). The convergence of results was established by comparing the borehole values derived from the open-ended WTP question and the series of dichotomous choice (DC) questions.

To enhance the reliability of CVM estimates Mitchell and Carson (1989) suggest the use of sufficiently large sample sizes and robust statistical techniques that guard against undue influence by outliers. Sample size selection was determined by time and resource constraints and reflects the exploratory nature of the study. Wherever appropriate medians, as well as the means, are presented to indicate the potential biases due to outliers. By using geometric means, the effects of outliers is already much reduced.

Results

The mean WTP values derived in the survey for respondents without access to a borehole imply a value of securing access to a borehole that is slightly less than the costs of installing a borehole (Table 1). These differences might be expected however, as the amount that individuals pay to have a borehole installed reflect their expectations of the utility they will derive from the borehole over its expected lifetime. In contrast, the WTP value derived in this survey reflects the value to the respondent of securing access to the borehole. In multiplying the stated WTP by the number of sharing households, a linear demand curve is assumed which is likely to underestimate the true value of the borehole.

Table 1. Mean, 95% confidence intervals and median WTP values for a fifth share in a hand borehole for respondents without access to a borehole (N=182). The mean and likely range of costs of actually installing a borehole are included for comparison.

	WTP (Z\$)	Actual Costs (Z\$) / 5
Mean	248	370
95% CI	205 - 301	NA
Median	201	NA
Range of actual costs		324 - 414

The value of a Blair toilet, as calculated from respondents' stated WTP for a fifth share in a borehole were very close to the expected cost of building the toilet (Table 2). The closeness of these results are indicative of the criterion validity of the elicited WTP values and suggest that the standardised scores, multiplied by the WTP for the borehole, do yield valid estimates of the values of other categories.

Table 2. Mean, 95% confidence intervals and median value for a Blair Latrine derived from open ended WTP responses (n=357). The expected mean and range of costs of actually building a Blair latrine are included for comparison.

	Value from WTP (Z\$)	Actual cost (Z\$)
Mean	217	260
95 % CI	169 - 277	NA
Range	NA	238 - 291
Median		NA

The similarity of borehole values derived from open-ended WTP and dichotomous choice questions suggests the constructs used to establish these values were valid (Table 3). The difference between these two values and the WTA compensation values follow the trends frequently found in the literature (Mitchell and Carson, 1989). Based on the work of Hanemann, Mitchell and Carson (1989) suggest that, contrary to existing beliefs, WTP and WTA values could be expected to diverge significantly when there are few close substitutes for the goods in question. This is certainly true of boreholes in rural areas where, in terms of cost and quality, there are few close substitutes.

Table 3. Mean, 95% confidence intervals (CI) and median responses for open ended willingness to pay (WTP) and dichotomous choice (DC) borehole valuations and willingness to accept compensation (WTA) for borehole loss.

	WTP (Z\$)	DC (Z\$)	WTA (Z\$)
Mean	221 ^a	186 ^a	502 ^b
95% CI	195-252	164-210	440-574
Median	201	151	501
N	358	359	358

Disimilar superscripts indicate means significantly different at $p < .001$

Tests to establish the theoretical validity of the survey results were less conclusive. It was expected that WTP would be positively correlated with wealth, years of education and would be related to sex (the WTP of females would be greater than that of males), the rainfall of the area (the mean WTP in the highest rainfall area would be less than the mean WTP in the lowest rainfall area) and the source of household drinking water supplies (the mean WTP of those whose water came from wells or boreholes would be less than the mean WTP of those whose water came from other sources).

Pearson correlation coefficients for WTP with wealth ($r=0.09$, $n=358$) and number of years education ($r=0.08$, $n=358$) showed the expected positive relationships but the coefficients were too small to signify meaningful relationships. T-tests of the mean WTP for males and females showed no significant differences at $p<.05$.

The mean WTP in the high rainfall Mangwende area, was significantly lower than that in the low rainfall Chivi area ($t=4.2$, $df=234$, $p<.001$) (Table 4). Due to there being only a single replicate of each agro-ecological area in the survey design we cannot be sure however, that these are rainfall and not site effects.

Table 4. Mean, 95% confidence intervals (CI) and median responses for open ended willingness to pay (WTP) for a fifth share in a borehole in a high rainfall area (Mangwende) and a low rainfall area (Chivi). Means were significantly different at $p < .001$.

	Mangwende (Z\$)	Chivi (Z\$)
Mean	184	331
95% CI	130 - 217	272 - 402
Median	201	301
N	112	124
a Significantly different at $p < .001$		

Mean WTP for those whose water source was a well or borehole was Z\$200 (95% CI: 174 - 231, $n=282$) whilst for those whose water source was a dam, river or other source, the mean WTP was Z\$321 (95% CI: 245 - 422, $n=76$). These values were significantly different ($t=3.0$, $df=356$, $p < .003$).

It would be expected that, wealth effects being equal, the value of tree resources would increase with decreasing availability. Correlation of the total value of tree resources, derived from the WTP values, against tree cover showed the expected negative relationship ($r=-0.03$, $n=357$) but the coefficient is too small to facilitate much confidence in the relationship.

Whilst the data only weakly conform to theoretical expectations the similarity between actual borehole and Blair toilet installation costs and the values derived from WTP questions and the similarity of WTP and DC values provide reasonable grounds for accepting the validity of survey results.